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IRRADIATION SICKNESS¹

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PATIENTS receiving heavy doses of irradiation frequently develop anorexia, malaise, nausea, and vomiting. Holmes and Hunter (1) have described three different types of this indisposition: first, "toxic sickness" resulting from the destruction of large masses of tumor tissues; second, "psychic sickness" produced by the association of the odors of the radiological department with a real reaction which has occurred at a previous visit; third, "true irradiation sickness" which is the symptom-complex resulting from the effects of x-rays or radium rays on the normal structures of the body. This paper deals only with true irradiation sickness, which has become increasingly important with the adoption of fractional doses and prolonged periods of treatment. Since very little is known about the cause of this condition a great deal has been written about it. A perusal of the literature of the past thirty-three years shows that more than thirty authors have at one time or another championed one or more of the following etiological factors:

1. Inhalation of nitrous gases and ozone in the treatment room.
2. The building up of static electricity in the patient's body.
3. Changes in sodium, calcium, and potassium metabolism.

4. Disturbances in chlorine metabolism.
5. Changes in the vegetative nervous system.
6. Changes in blood cholesterol.
7. Cholin poisoning.
8. Glycogen dwindling.
9. Endocrine imbalance.
10. Allergic phenomena.
11. Disturbance of acid base equilibrium.
12. The production of a roentgen toxin in the blood.
13. Stimulation of enzymes which produce tissue autolysis.

Since such a variety of causes has been assigned to this troublesome malady one is not surprised to discover that many plans of treatment have been recommended and many authors feel that their remedies may be specific. Some of the substances recommended are: intravenous saline solution (isotonic to 10 per cent), intravenous glucose solution (5 to 25 per cent), sodium chloride, calcium chloride, afenil, colsil, vasano, nautisan, permesin, ephetonin, sympatal, cardiazol-ephedrine, insulin, hypophyseal and suprarenal extracts, a resistant strain of colon bacilli, magnesium hyposulphite, intravenous magnesium thiosulphate, intramuscular liver extract, and nembutal.

¹ Presented before the Fifth International Congress of Radiology, in Chicago, Sept. 13-17, 1937.

Obviously, little progress can be made until the mechanism of this reaction is better understood. It has been known for

the toxic symptoms consisting of anorexia, vomiting, diarrhea, and death which followed the application of heavy doses of

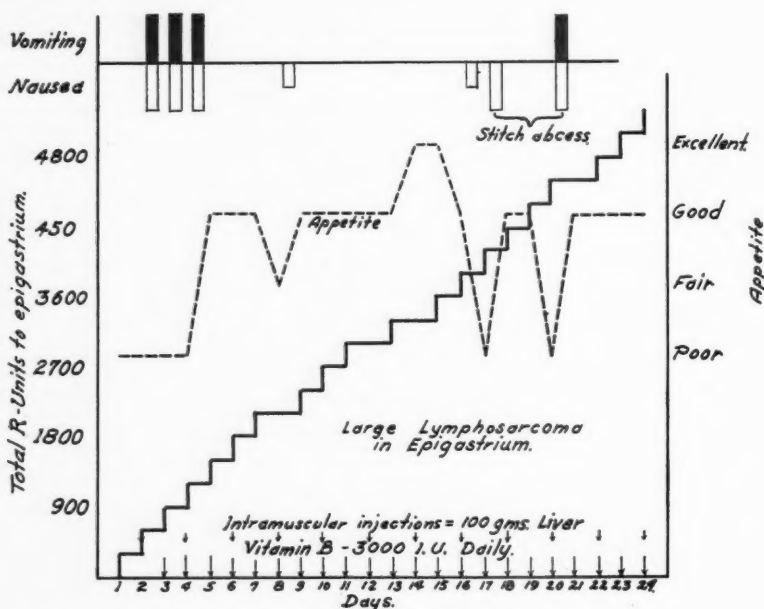


Fig. 1. In this case a large tumor overlying the head of the pancreas completely blocked the common bile duct and a drainage tube had been placed in the gall bladder. Although liver extract was started on the second day, nausea and vomiting followed each x-ray treatment until two days after vitamin B₁ was started. Improvement in appetite was then marked except for a few days when a stitch abscess appeared and was opened.

years that "true irradiation sickness," severe enough to require treatment, results only when certain portions of the body are irradiated. In our opinion some portion of the intestinal tract or the parotid gland must be included in the treated area for serious symptoms to be produced. We also believe that areas treated over the upper abdomen produce more severe symptoms than those treated over the lower abdomen because the intestine becomes more sensitive as it approaches the stomach. Although little has been written about the effect of x-rays on the parotid, we have found it possible to eliminate most of the untoward effects following irradiation of the head and neck by efficiently shielding these very sensitive structures.

Hall and Whipple (2), in 1919, described

filtered x-rays to the abdomen in dogs. In an article (3) published in 1920, one of us (C. L. M.) showed that a similar reaction characterized by loss of weight, a reduction in urine output, diarrhea, anorexia, and eventual death could be produced in rabbits *only* when some portion of the abdomen was irradiated. These findings were substantiated in 1922 by Warren and Whipple (4), who found it possible to produce their severe reactions in dogs *only* when some portion of the abdomen was irradiated. They described microscopic changes in the small bowel, consisting of more or less complete necrosis of the epithelium of the crypts and villi, which they thought were of great significance. In fact, they concluded that the intoxications observed in their animals were due to

injury produced in the epithelium of the small intestine. Martin and Rogers (5, 6) later studied the cachexias produced in dogs

We began by experimenting with drugs capable of depressing the vomiting center and thereby relieving nausea and vomiting

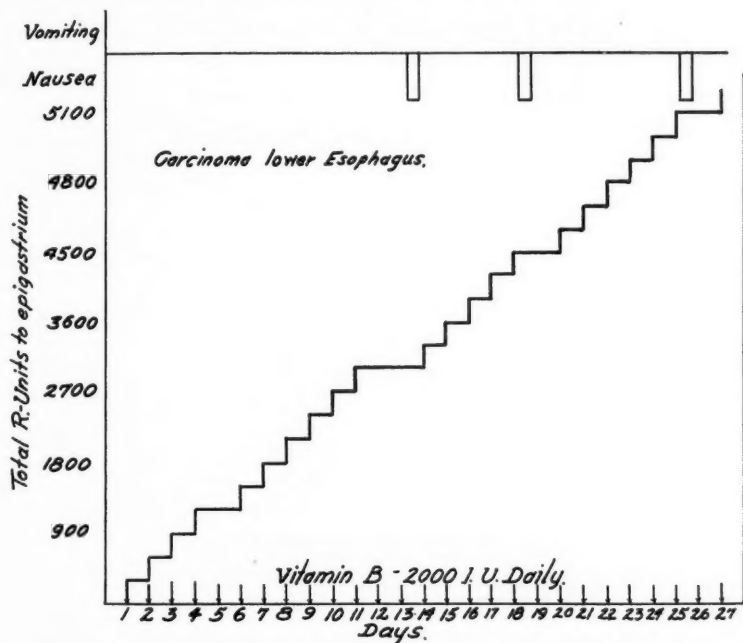


Fig. 2. In this case a large carcinoma partially blocked the lower esophagus and extended into the fundus of the stomach and a gastrostomy had been done. Although 300 r was directed through a 15 cm. port almost every day toward the epigastrium, using 220 kv. and a heavy Thoraeus filter, very little nausea and no vomiting occurred.

by administering heavy doses of x-rays to isolated loops of small bowel, and published a photograph of the dilated discolored loops of small intestine observed in a dog dying from the effects of a very intense dose of x-rays given to the entire abdomen. A few years later an attempt was made by the same authors to study the intoxication produced by irradiation of the parotid but none of the laboratory animals showed reactions following such irradiation and it was soon learned that the parotid glands of small animals do not respond like those of the human species.

Since we were convinced many years ago that true irradiation sickness was in most instances produced by an interference with intestinal physiology, we have searched for remedies capable of counteracting functional disturbances of the intestinal tract.

temporarily, some ten years ago, knowing, of course, that these remedies served only to relieve symptoms and were in no way specific. At first the best results were obtained with chloral hydrate and the bromides, but even when 20 gr. of chloral hydrate and 60 gr. of sodium bromide, a rather heroic dose, were given by rectum, symptoms were often alleviated for only two or three hours. Our attention was then shifted to barbitol which produced a more lasting effect, and about six years ago amytal was adopted in our clinic as the best available remedy. This substance was given in doses varying from 3 to 10 gr. depending upon the age of the patient and the severity of the symptoms, and long remissions resulted. Of course, depression and stupor may result from this form of therapy. The drug market is now flooded

with a huge number of barbituric acid derivatives, but they are all capable of producing sleep and depressing the vomiting

cutaneously or intravenously, produce marked improvement in the toxemia resulting from intestinal obstruction. Since,

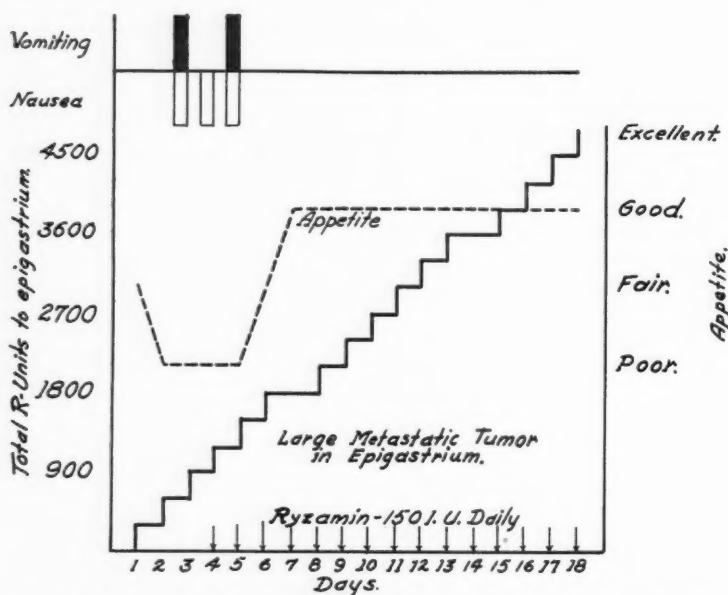


Fig. 3. This patient had a large metastatic tumor in one of the mesenteries of the upper abdomen. She received 300 r daily through large ports of entry and complained of nausea and vomiting until two days after vitamin B₁ therapy was started. Her appetite then improved and she had no further trouble.

center in most individuals. Some of the preparations now available are amytal, phenobarbital (luminal), ortal, ipral, neonal, allonal, nembutal, nembural, seconal, and veronal. Many of these drugs are sold in the form of sodium salts which are soluble in water, and, therefore, suitable for rectal administration in solution. Some of them are made up in the form of suppositories which are very valuable in the presence of vomiting. Richards and Peters (7) have called attention to the fact that barbiturates are contra-indicated in the presence of liver disease, and we have encountered a few cases in which a marked excitement followed their use, but in most instances their palliative effect is quite satisfactory.

Haden and Orr (8) showed very conclusively some twelve years ago that sodium chloride solutions, given either sub-

according to our theory, many irradiation reactions are toxemias resulting from intestinal damage, it seems reasonable to assume that the same type of therapy might be successful, and many authors have advocated the use of sodium chloride. Patients who are vomiting need food and water as well, and our best results have been obtained from the intravenous administration of a liter of 5 or 10 per cent glucose made up in normal salt solution. This medication can be given repeatedly and is particularly helpful in the treatment of cases having abdominal masses which are producing partial intestinal obstruction. Holmes and Hunter believe that a high carbohydrate intake is very helpful, and give their patients stick candy and fruit drinks containing large amounts of lactose, in addition to intravenous glucose.

Intravenous medication is not a simple

procedure nor is it entirely pleasant, and the irradiation therapist would like to have at his command some efficient preventive which could be given by mouth without the production of untoward symptoms. Nembutal, as recommended by Richards and Peters and Popp (9), is easy to administer but it does not really strike at the cause of the toxemia and it keeps the patient in a state of drowsiness.

In casting about for substances which play a rôle in intestinal derangements, our attention during the past year has been drawn to vitamin B. Davis (10) states that a lack of vitamin B₁ produces anorexia and degenerative changes in the intestinal tract, consisting of reduction in the size of the villi, decreased absorptive capacity, decreased vigor of the intestinal musculature, and vascular and trophic changes in the mucosa; while a lack of vitamin B₂ produces vague digestive upsets, diarrhea, and pellagra. The similarity between these symptoms and findings and those observed in animals receiving large doses of x-rays over the abdomen is at once apparent. Russell (11) and others have reported a marked improvement in appetite after the administration of vitamin B₁ in such serious diseases as pernicious anemia and sprue, and Dietel and Probst (12) and Young (13) have produced some encouraging results in irradiation sickness by the intramuscular injection of liver extract. Although many workers claim that this substance contains vitamin B₂, Collazo and Sánchez Rodriguez (14) feel that their experiments show that the common hepatic extracts contain only vitamin B₁.

Since the chloride of vitamin B₁ can now be obtained in pure crystalline form for both oral and intramuscular use we felt its effectiveness should be investigated. A series of animal experiments was first carried out in an effort to show that this substance might be capable of producing protection against the lethal abdominal dose of x-rays. From this work, which has been reported elsewhere, we learned that although small animals could not be uniformly protected, large doses of vitamin B₁

seemed to definitely prolong the lives of some of them.

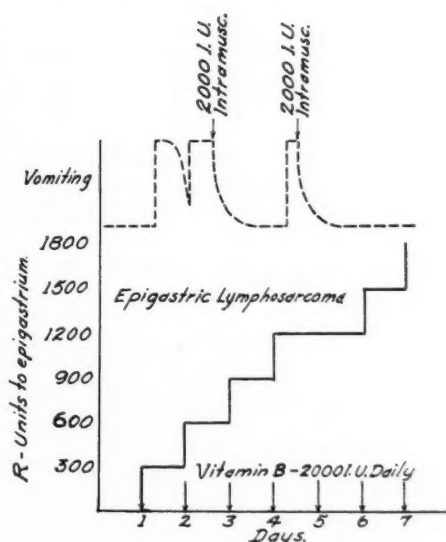
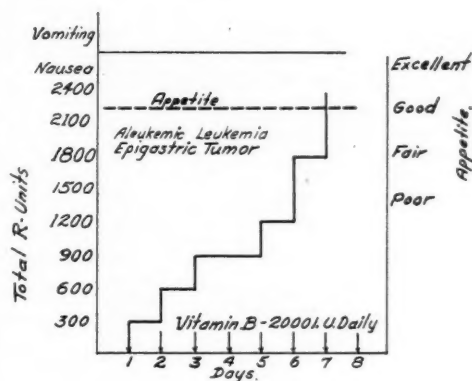


Fig. 4 (above). During a previous admission when she received exactly the same x-ray treatment over the epigastric this patient was quite ill during the entire series. However, although the tumor was equally as large, at this visit she had no gastro-intestinal symptoms and was quite comfortable.

Fig. 5 (below). On two occasions this patient had an attack of vomiting after an x-ray treatment while taking vitamin B₁ by mouth. Intramuscular injections of the vitamin stopped the vomiting instantly both times.

It was then thought worthwhile to try the substance in clinical practice. The preparations available to us were Ryzamin-

B, a substance made from rice polishings by Burroughs-Wellcome; Betaxin, made by the Winthrop Company, and Vitamin

held by a small spoon provided with the tube contains 50 international units (I.U.) of vitamin B₁. Betaxin is put up as a

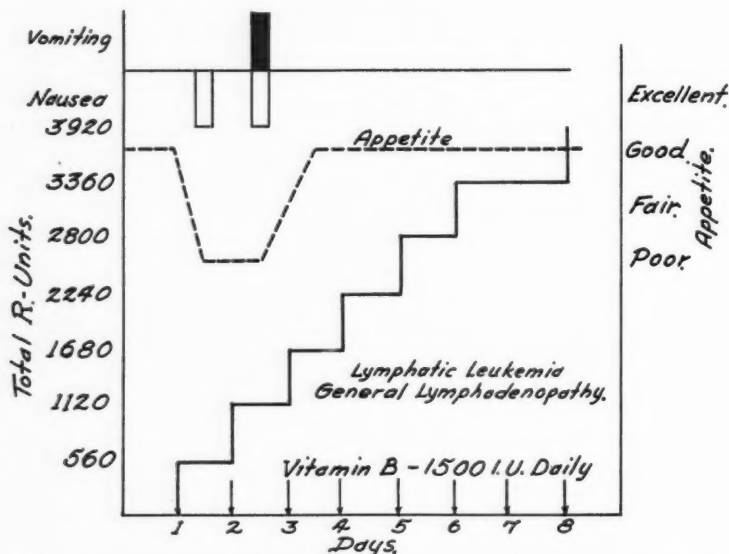


Fig. 6. Although 560 r was given to large groups of leukemic glands on successive days, no gastro-intestinal symptoms were noted after the vitamin B₁ therapy was continued for two days.

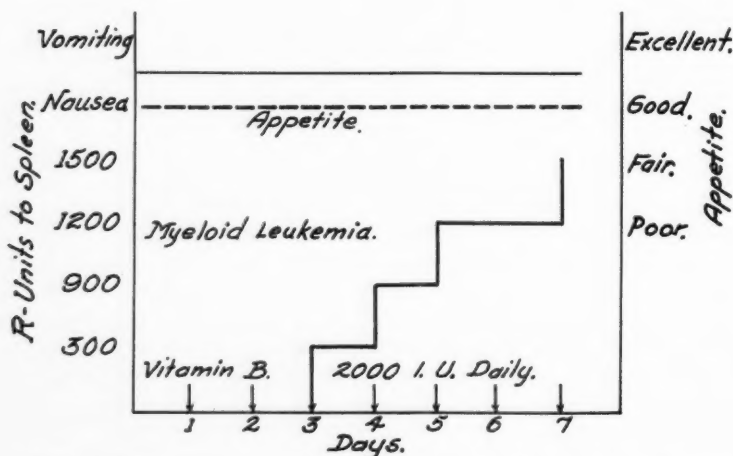


Fig. 7. Severe reactions can be expected regularly when 300 r is given daily to a very large spleen through 20 cm. ports in myelogenous leukemia. In this case the vitamin B₁ was started two days in advance of the x-ray treatment and no gastro-intestinal symptoms were noted at any time.

B₁, made by Abbott & Company. Ry-zamin-B is put up in a sweet syrup-like mixture in a flexible tube and the amount

tablet containing 500 international units and in fluid form as a 1,000 I.U. ampule for intramuscular injection. The tablet manu-

factured by Abbott contains 1,000 I.U. and their ampule for intramuscular use contains 2,000 I.U. At first doses of only form of medication not only reduced or completely abolished all nausea, but it enabled the patients to enjoy most of their

TABLE I.

	Diagnosis	Irradiation	Medication	Results
1.	Epigastric retroperitoneal lymphosarcoma	300 r daily to one of two 15 cm. ports for 20 treatments	Vitamin B ₁ —3,000 I.U. daily. Liver extract 100 gm. every second day	Nausea and vomiting during first three days of treatment
2.	Large metastatic epigastric tumor from carcinoma of cervix	300 r daily to one of two 20 cm. epigastric ports for 16 treatments	Ryzamin — 150 I.U. Vitamin B ₁ daily after fourth day	Nausea and vomiting stopped on day after vitamin B ₁ started
3.	Large epigastric tumor from aleukemic leukemia	300 r daily to one of three 20 cm. ports over upper abdomen for six treatments	Vitamin B ₁ —2,000 I.U. daily sodium amytal gr. 3 each night for sleep	Appetite good and no nausea through series
4.	Carcinoma of lower third of esophagus	200 r to two 10 × 15 cm. areas over upper abdomen and lower chest daily for 20 treatments	Vitamin B ₁ —150 I.U. daily given as Ryzamin	No nausea. Fed through gastrostomy tube
5.	Carcinoma of lower third of esophagus and fundus of stomach	200 r to two 10 × 15 cm. areas over upper abdomen and lower chest daily for 20 treatments	Vitamin B ₁ —1,500 I.U. daily through gastrostomy tube	Only slight nausea and no vomiting
6.	Carcinoma of lower third of esophagus and fundus of stomach	300 r daily to one of three 15 cm. areas over abdomen and lower chest for 24 treatments	Vitamin B ₁ —4,000 I.U. daily through gastrostomy tube	Slight nausea on three occasions. No vomiting
7.	Large epigastric tumor from Hodgkin's disease with common duct blocked	300 r daily to one of three 15 × 20 cm. areas over epigastrium for six treatments	Vitamin B ₁ —2,000 I.U. daily. Sodium amytal gr. 6 some nights for sleep	Vomited once after each of first three treatments. Appetite good throughout series
8.	Large epigastric tumor secondary to lymphosarcoma of rectum	300 r daily over one of three 20 cm. areas over upper abdomen for six treatments	Vitamin B ₁ —2,000 I.U. daily. Vitamin B ₁ —2,000 I.U. intramuscularly twice for vomiting	Vomiting after two treatments relieved at once by intramuscular vitamin B ₁
9.	Carcinoma of antrum of stomach	300 r daily to one of three 15 cm. ports over upper abdomen for 24 treatments	Vitamin B ₁ —2,000 I.U. daily	Vomiting on one day only. Appetite good as at admission
10.	Huge spleen from myelogenous leukemia	300 r to one of 20 cm. areas over spleen daily for four treatments	Vitamin B ₁ —2,000 I.U. daily beginning two days before x-ray therapy	No nausea. Ate three good meals daily throughout series

150 I.U. per day were used, but we were soon convinced that larger doses were more effective and at present many patients are receiving 2,000 I.U. daily. The drug is given by mouth and intramuscular injection is resorted to only when vomiting occurs. We were soon convinced that this

meals and to maintain their nutrition even while receiving a long series of treatments over the abdomen.

In many instances nausea and vomiting occurred during the first few days of treatment but completely disappeared during the remainder of the period which often

lasted for several weeks. Since in these cases vitamin therapy had been begun on the first day of irradiation it occurred to us that several days were required for the body to become saturated with the substance. For this reason 2,000 I.U. are now given daily for at least two days before the x-ray treatment is started and we feel that this procedure has definitely minimized the symptoms noted during the early period. That saturation is necessary for relief is also indicated by the fact that when vomiting occurs it can frequently be relieved almost immediately by the intramuscular injection of 2,000 I.U. of vitamin B₁.

More than fifty patients receiving irradiation for a variety of conditions have been treated with vitamin B₁, but it is our opinion that case reports should be limited to those cases receiving x-ray treatment over the upper abdomen because some degree of sickness can be expected regularly following this procedure. Our clinical experience with ten such cases is tabulated in Table I. In none of these patients except the last one was preliminary vitamin B₁ therapy used, but the results obtained with this case were so good that we believe most of the patients could have been relieved of their early symptoms if the plan had been used throughout the series.

In our clinic the following routine orders for patients about to undergo heavy irradiation has been adopted:

1. A high carbohydrate diet.
2. Vitamin B₁, 2,000 I.U. daily by mouth beginning two days before the irradiation is started.
3. If vomiting occurs, give vitamin B₁, 2,000 I.U., intramuscularly at once.
4. If relief does not occur within 30 minutes, give sodium amytal, gr. VI, or an equal amount of another soluble barbituric acid derivative by rectum, or insert a nembutal suppository.
5. If vomiting persists, give one liter of

5 per cent glucose in normal salt solution intravenously, and repeat if necessary.

We have not found it necessary to give intravenous glucose to any of the patients treated with vitamin B₁. As a rule this medication is needed only when some serious complication such as partial intestinal obstruction or abdominal infection is present.

SUMMARY

1. Barbiturates and intravenous saline and glucose solutions have a definite palliative effect on irradiation sickness.

2. Vitamin B₁ given in large doses often prevents all the symptoms and seems to have a more specific effect.

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ROENTGENOLOGIC ASPECT OF SILICOSIS¹

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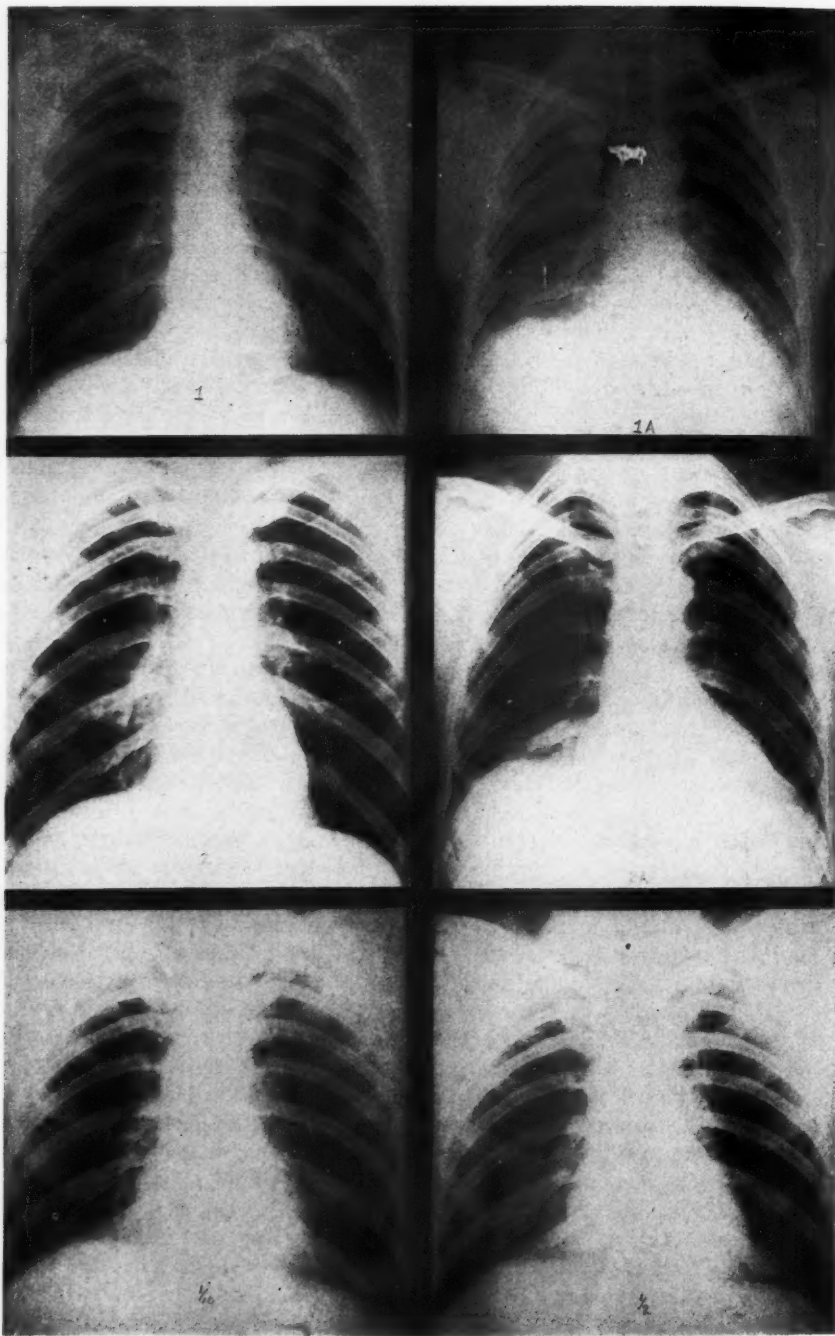
IT has been my observation that there is lacking sufficient appreciation of the important rôle played by roentgenology in the early diagnosis of silicosis of the lung structures. Renewed widespread interest in the unfortunate individuals so afflicted is beginning to be manifested by the medical and legal professions, as well as the industries in which occupational disease is truly an economic problem. I might include also those manufacturing plants in which the non-silica dust problem is but a pseudo-hazard. Nevertheless, the added difficulties of the defense of such unjust claims has created even greater economic chaos, and renewed interest in the scientific and diagnostic phases of this problem is a most timely reaction.

Therefore, my object in stimulating interest in this symposium is due to the self-evident fact of the ever-increasing importance and responsibility of the roentgenological considerations in the early diagnosis of silicosis. I realize, also, the desirability of a group discussion and correlation of the pathological and clinical phases with all of which we roentgenologists should be fully acquainted before finally arriving at the proper differential diagnosis.

The various methods of lung examinations have their individual limitations and the early roentgenological diagnosis of silicosis is no exception. The lungs are formed, as most of you know, by multiple ramifications of the bronchi, bronchioles, and terminal expansion type of bronchioles. From a roentgenological, diagnostic, and prognostic standpoint, these latter terminal bronchioles are very important anatomical structures. The *vestibule*, the three to six *atria*, and the two or more *infundibula* together form the primary units or lobules of a normal lung. Throughout

these primary units or lobules of the lung there are interlaced important superficial deep systems of lymphatics. An important function of this latter deep lymphatic group is to take care of the stray or foreign matter particles while the blood vessels deal with possible noxious substances that may be present in solution. A thorough understanding of these primary units beyond the roots of the lung is fundamental knowledge, the scope of which every radiologist should thoroughly visualize as the final line of defense of the lung against the invasion of foreign substances. This can occur only after the actions of the lining ciliated epithelium and the muscles of the walls of the air passages have failed in their endeavor to protect the lung. Equally so, the roots of the lung in relation to the bronchial lymphatics, glandular and vascular structures should receive intensive study, since they usually show such a variety of connective thickening tissue due to old infections, sinus disease, or abnormal vascular densities, when primarily silica is not the etiologic factor. All of these lines of future research will require most intensive study in the direction of correlating the available data in co-operation with the pathological findings of sections of the lung areas involved, and the serial examinations of normal and hazardous lung dust cases—not unlike the pioneer work in tuberculosis so ably conducted by the many workers and members of this Society when the early roentgenologic diagnosis of this disease was at stake. The many physiological and chemical phenomena should be given equal considerations, as well as the most helpful work of our colleagues in the Public Health Service and the mining industries. From a technical roentgenologic standpoint, there is room for improvement in at least two directions. I will discuss some of these problems during the lantern-slide projections.

¹ Read before the Radiological Society of North America, at the Twentieth Annual Meeting, at Memphis, Tenn., Dec. 3-7, 1934.



Figures 1 to 6 illustrate the normal chest (of the author) taken during the inspiratory and expiratory cycle. The variety of technics are the methods routinely employed for this purpose by many physicians and radiologists. Fig. 1 (*upper left*). Inspiration ($1/20$ sec., 6 ft. F.T.D., 62 kv., 400 ma.). Fig. 2 (*upper right*). Expiration ($1/20$ sec., 6 ft. F.T.D., 67 kv., 400 ma.). Fig. 3 (*middle*

Since I believe the more exacting roentgenological considerations are increasing in their importance in the field of diagnosis of lung dust problems, an introspection as to the position and responsibilities of the roentgenologist will not be amiss. If the x-ray film merely indicated silica as an opaque rock or crystalline foreign body, a simple fluoroscopic examination would suffice. Instead, we find indirect but characteristic evidence of healthy lung reaction opacities to abnormal and continuous inhalation of certain forms of foreign dust particles. Again, these lung changes may vary in proportion to the quantity, rate, and duration of the exposure to silica dust, as well as to the size and type of the particles.

Unfortunately the early or pioneer work in pneumoconiosis was, of necessity, based on x-ray film studies made with portable machines or technical roentgen methods considered unreliable to-day. The true picture of even normal lung structures was incorrectly projected upon the x-ray film; pathological tissue changes were likewise distorted. Therefore, during the period preceding the year 1928 it was to be expected that controversial opinions were expressed regarding the diagnosis of pneumoconiosis, as they were in the roentgen diagnosis of early tuberculosis prior to the World War. Many of you here will remember that it was not uncommon for the inexperienced clinician and some roentgenologists to diagnose incipient tuberculosis in the adult on the basis of intensified or unusually prominent glandular and linear peribronchial and hilar opacities. This was equally true of the silicosis problems prior to the period of intensive research, postmortem studies, and the accumulation of statistical data on large series of cases by several of the scientists who are taking part in this program.

Simple silicosis not complicated by infections or tuberculosis should be roentgenologically diagnosed reasonably early and

with accuracy. In the near future many of the controversial phases should be eliminated in view of the added knowledge and experience based on carefully analyzed histological researches made available for use to-day.

The pathological postmortem studies of Dr. Gardner have been of the greatest help in this direction. During the past three or four years intensive examinations of localized enlargements of suspicious lung-fields on the original x-ray film have been studied and have aided us materially in the diagnosis of extremely early and questionable silicosis. The limits of our efforts at enlargements have been five and a half times the original lung-fields, but apparently this degree of enlargement is sufficient for differential diagnostic purposes. Improved finer grain films and intensifying screen textures may broaden the scope and future practical employment of this method as a research and an accessory diagnostic procedure. The future preliminary education of the physician specializing in the diagnosis of these occupational diseases should include a rather comprehensive practical experience, and by all means include interpretation of various types of lung diseases and the many possible thoracic, mediastinal, and upper respiratory tract complications. Such an experience should not be limited to lung dust examinations alone.

Unquestionably the lung specialist should have studied occupational dust conditions from every possible angle and should have followed the clinical course of the disease from its incipency by means of serial lung studies of known silicosis cases over a period of many years. A most invaluable requisite or background is an unusually broad roentgenological diagnostic experience.

Hand in hand with experience, the practical roentgenologist realizes that there are certain essential technical requirements in order that the correct interpretation of x-ray films may be possible. The ideal x-ray

left). Inspiration ($1/20$ sec., 3 ft. F.T.D., 45 kv., 400 ma.). Fig. 4 (*middle right*). Expiration ($1/20$ sec., 3 ft. F.T.D., 50 kv., 400 ma.). Fig. 5 (*lower left*). Inspiration ($1/10$ sec., 3 ft. F.T.D., 78 kv., 100 ma.). Fig. 6 (*lower right*). Inspiration ($1/2$ sec., 3 ft. F.T.D., 58 kv., 100 ma.).

examination projects the normal and abnormal thoracic densities upon a film true to size, shape, and outline, and devoid of

cannot be placed upon the absolute requisite of a perfect x-ray exposure film, one that can be reproduced year after year,

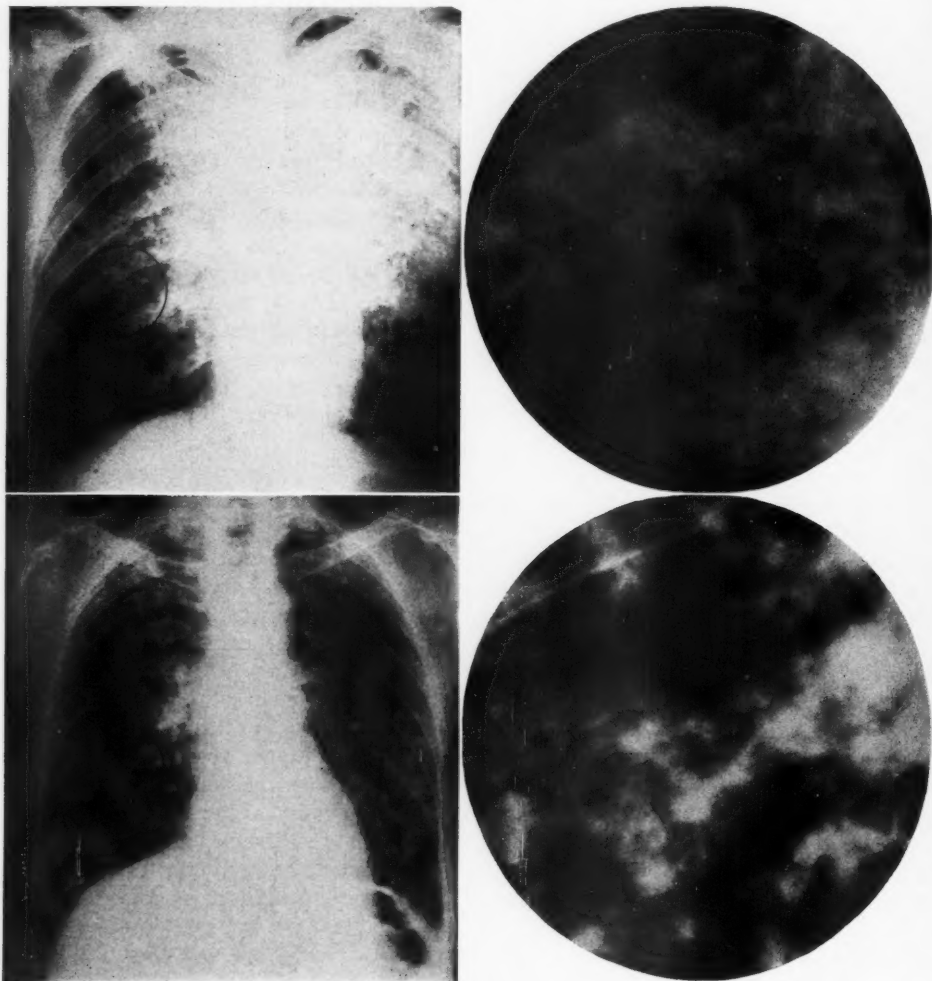


Fig. 7 (above) illustrates a moderately advanced case of blastomycosis, with accompanying enlargement shown in Figure 8 (right).

Fig. 9 (below) indicates metastatic lung involvements with marked emphysema, and an enlargement, Fig. 10 (right), of a one-inch circle localized lung-field as marked on the film shown in Figure 9.

movement or pulsations of the minute lung structures themselves. Distortion or exaggeration must remain at a minimum. It must be possible to review and differentiate the projected normal and pathological lung structures on a properly exposed x-ray film.

In my opinion too great an emphasis

clearly outlining the most minute lung structure changes, especially during the present diagnostic developmental phase of our problem; otherwise the diagnostic possibilities are of necessity limited.

The minimum requirements for an ideal set-up is an x-ray transformer developing from 400 to 500 milliamper capacity in a

tube containing a target focal spot no greater size than 4.5 millimeters, 6-foot target-film distance, with an exposure time

more desirable since the focal spot is but one-third as large as the above minimum requirements, thus projecting the more

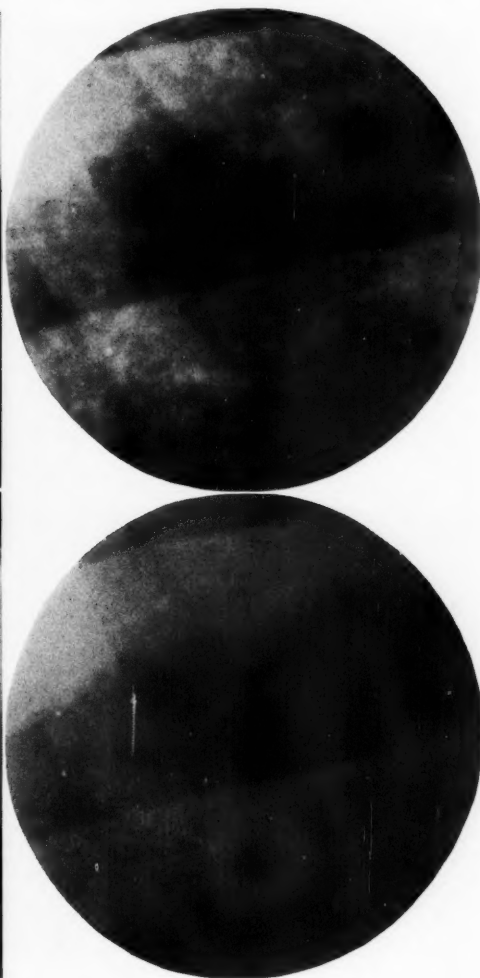
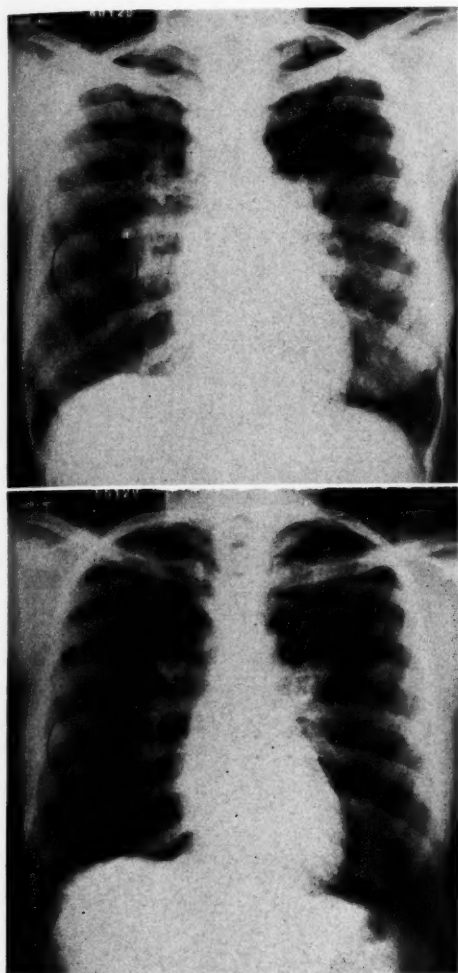


Fig. 11 (*upper left*). This film presents an interesting case (patient Mrs. O. T.) of peripheral thickening and atypical elongated nodulations, somewhat suggestive of miliary tuberculosis. The patient entered the Barnard Free Skin and Cancer Hospital (service of Dr. M. Engman, referred by Dr. C. W. Lane), complaining of a persistent skin eruption throughout the past year, involving the lower extremities, and later the body and arms as a whole. The biopsy indicated giant cells, necrotic tissue areas, and atypical suggestive tuberculous findings.

Fig. 12 (*upper right*). This enlargement ($5\frac{1}{2} \times$) indicates a lower right lung-field which is most interesting when compared with a silicotic field enlarged to the same degree.

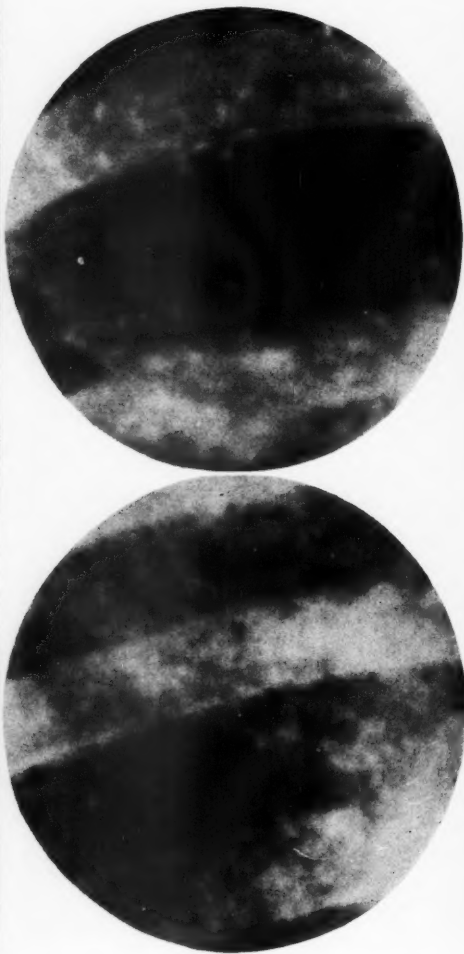
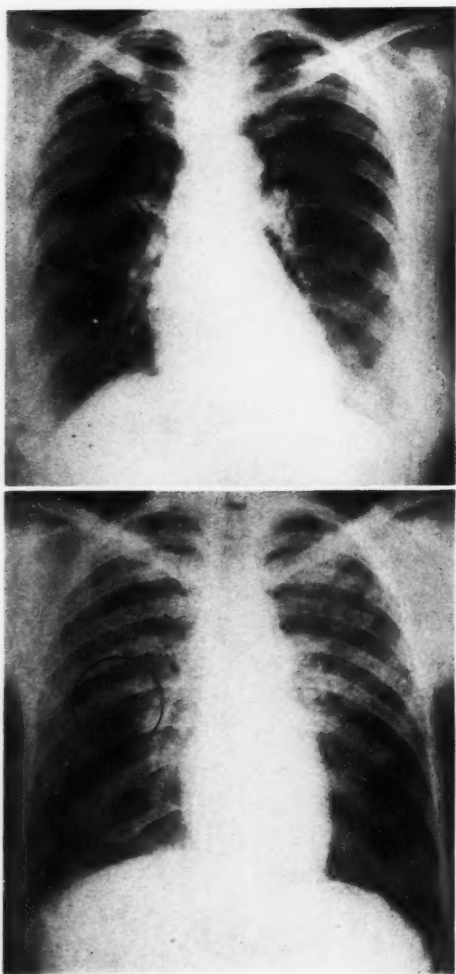
Fig. 13 (*lower left*). This film shows an examination several months later of the same thorax and, to our surprise, indicated a disappearance of the previously observed nodulations. The patient remained symptom-free with negative clinical findings throughout the chest, and elsewhere, and has remained so for many years. The eruption has disappeared. The final diagnosis was a fungus type of infection. This is the third case of the mycositic type which simulated a silicotic lung.

Fig. 14 (*lower right*). This film indicates an enlargement ($5\frac{1}{2} \times$) of a one-inch circle of a lower right lung-field, which now appears relatively clear.

of one-twentieth of a second. The new minute lung shadows with even greater de-
rotating target type of x-ray tube is even tail and accuracy upon the x-ray film.

It will be impossible at this time to adequately discuss all of the important requisites of a complete x-ray examination,

diagnosis in questionable cases, or for the exclusion of other types which might simulate silicosis when initially examined.



Figs. 15 and 16 (*above*). These present the frequently observed calcified, sharply defined nodulations suggestive of healed tuberculosis and the enlargement of a small circumscribed area of the same lung ($5\frac{1}{2} \times$), as shown in Figure 16 (*right*).

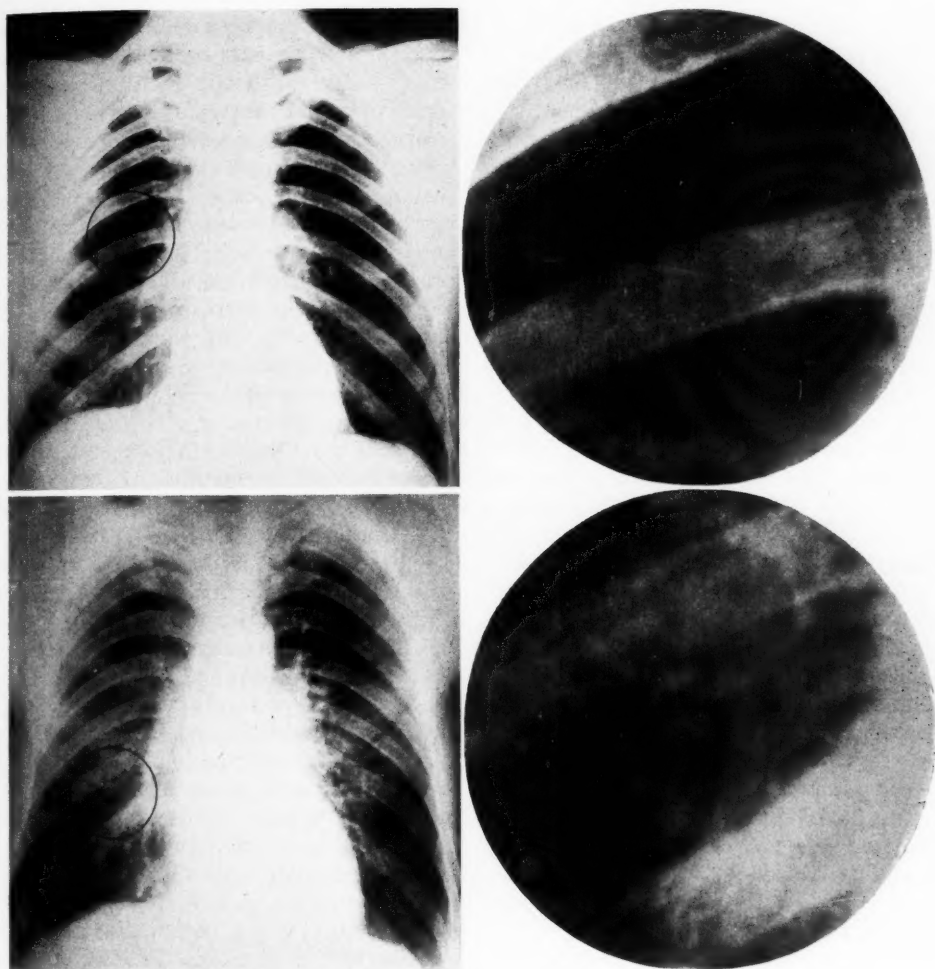
Figs. 17 and 18 (*below*). These illustrate a typical case of acute miliary tuberculosis and the enlargement of an inch circle lung-field ($5\frac{1}{2} \times$), as shown in Figure 18 (*right*).

but an evaluation of a few of the essential requirements will not be amiss. Stereoscopic film studies are always preferable to single exposures, although this method is not always practical. Serial films made at intervals of every six or twelve months are absolutely essential in arriving at a final

Lateral views are always helpful, both in the early and advanced cases of lung dust conditions. Another requisite is taking advantage of a broad knowledge based on experience in differentiating x-ray film shadows of unusual lung patterns, and normal but intensified bronchial markings,

from those unusual lung structure projections, and peripheral reactions or congestions, which are pathological yet not due to silicosis.

structures are too light, the necessary lung detail is lost; dark or over-developed films are of little diagnostic value, for early lesions may be overlooked. The potential



Figs. 19 and 20 (*above*). These illustrate a normal healthy lung and the accompanying enlargement ($5\frac{1}{2} \times$), as shown in Figure 20 (*right*).

Figs. 21 and 22 (*below*). These show a nodulated lung-field with a minimum amount of silicosis, involving the peripheral lung structures. It is interesting to study the enlargements of these cases, as shown in Figure 22 ($5\frac{1}{2} \times$) from a differential diagnostic standpoint (*right*).

Space will not permit me to show all of the various stages of silicotic nodulations. I have examined hundreds of questionable lung-fields by this enlargement method and found them to be most helpful from a differential diagnostic standpoint.

The technical considerations, in my opinion, are vital issues and therefore require a most critical analysis from the standpoint of the x-ray examination of the thorax. If the film shadows of the lung

current employed or strength of the x-ray beam is likewise important and should be accurately calculated for each chest examined. The patient should be carefully measured in centimeters and the probable

penetration of the chest thus estimated in terms of the number of kilovolts to be employed. Otherwise, the diagnostic value of an improperly exposed x-ray film is misleading and, in fact, unreliable from the standpoint of early diagnosis of any and all types of lung infections as well as silicosis.

The size of the focal spot of the x-ray tube is another important consideration. If too large, the shadows of the chest, including both the normal and the pathological structures, would be greatly exaggerated upon an x-ray film. The broad focal spot might be compared to the large "fast" lens of our present-day speed camera. It is possible to make very rapid exposures in subdued light with such an unusually large lens, but at the expense of depth or detail. If the lens or diaphragm is "stopped-down" to a very small opening, sharper photographs are obtained, but compensated by a longer exposure factor. This is also true when too small a focal spot is employed in the average low capacity x-ray tubes.

The distance of the tube from the film and patient is likewise an important factor. The greater the distance, up to six feet, when a broad target is employed, the more accurate is the projection of the chest image upon the film, but the x-ray beam is less intensive and a larger milliamperage output is required. However, both these greater distances and larger x-ray tube targets have their disadvantages in that an increased quantity of current, or milliamperage, is required. The capacity of the average smaller transformer is inadequate for the ideal rapid exposure technic. After all, the roentgenologist must select a happy medium between distance, voltage, and focal spot, but the time factor, in my opinion, should remain uniform and preferably less than one-twentieth of a second; otherwise, movements or pulsations of the lung structures cannot be excluded. Uniform reduplication of exposures over a period of many years is a most important requirement in serial lung examinations.

Many of our small x-ray machines require that the tube be placed relatively close to the patient and film—perhaps three

feet distant—due to the limited capacity of both the x-ray machine and tube. Usually from one-fourth to one second exposure is required under these conditions, but in the average group of cases, this type of film will unquestionably prove to be very unreliable and misleading from an early x-ray diagnostic recognition standpoint of apical tuberculosis, miliary tuberculosis, fungi diseases, blastomycosis, silicosis, etc. Comparative changes or developments cannot be accurately studied by such limited types or methods of making x-ray examinations. The hazard of movement and distortion of the lung structures can be controlled by one-twentieth second's exposures or less, and this blurring factor of the lung markings must be eliminated if the x-ray examination is to be considered ideal.

The size or habitus of the patient may show individual comparative lung differences, all of which variations are, however, considered normal for that particular type of chest. Whether the x-ray examination is made during deep inspiration or expiration is also an important factor from an interpretative standpoint. Very frequently we require both types of film in addition to a special study during the phase midway between inspiration and deep expiration in our examinations, especially when emphysematous changes are present. In the past some observers based their early positive silicosis findings on supposed pathognomonic changes of the peribronchial and hilar trunk shadows, but in the light of the most recent observations of serial studies of a large group of suspected cases, I have failed to observe any such typical roentgenological findings other than the basic discrete peripheral six millimeters or less lung densities, showing uniformity as to size and distribution, plus well defined borders surrounded by apparently normal shadows.

However, Dr. Gardner has discussed this matter in detail in relation to the comparative x-ray and pathologic autopsy findings. The more acute type of silicosis produces a somewhat different picture, a dif-

fuse intra-pulmonary haziness of uniform density, and must not be confused with the more chronic involvements under consideration in this presentation. The importance of serial examinations in relation to any acute lung condition cannot be over-emphasized. Occasionally the immediate analysis may be difficult but later films easily clear up the differential diagnosis and establish the presence of other lung complications. Various lung and vascular congestions that might grossly simulate early silicosis, including miliary tuberculosis, fungi infections, diffuse bronchial disturbances, asthmatic and bronchiectatic disturbances, must all be excluded in the final analysis by serial x-ray studies. Time will not permit me to discuss the silicotic conditions complicated by infection, since the x-ray and clinical studies may not infrequently require different types of examinations other than those discussed heretofore.

In closing, I wish to again emphasize the desirability of standard technical requirements, or shall I say minimum requirements of the ideal x-ray study for all lung conditions, including silicosis.

Let me again reiterate that the first six films (Figs. 1 to 6) are x-ray studies of the same chest, my own, and that all of these exposures were made within a thirty-day period. At least three of the chest films

do not appear alike. In fact, there are such wide variations in the character of the lung markings that many who viewed the original films concluded that they represented the lungs of different individuals. The technic was different for each individual chest examination, but the method was not unlike those routinely employed by many hospitals, offices, and medical departments of some of our industries. Three types of transformers and three different tubes were used in combination so as to obtain the greatest amount of efficiency and maximum capacity within the bounds of safety to the apparatus. The films, screens, and developing factors remained uniform. Therefore, this should prove conclusively the danger of attempting an early diagnosis of abnormal lung dust conditions, unless the x-ray film examination is known to be technically perfect according to the minimum standard requirements, which, I believe, are essential for interpretative purposes.

In addition, these x-ray findings must be correlated with the type of employment, concentration, and character of the dust, length of exposure, and the history and clinical observations; only under these conditions should a final conclusion as to the presence or absence of abnormal lung dust conditions be considered reliable and conclusive.

CLINICAL ASPECTS OF SILICOSIS

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IN presenting for discussion the clinical aspects of silicosis, it should be remembered that it is essentially a chronic, progressive disease. I am frequently asked by laymen, and occasionally by physicians, "How long does it take for a case of silicosis to develop or to produce disability?" As well ask, How long does it take heart disease to develop, or cirrhosis of the liver, or Bright's disease. We have one advantage with respect to silicosis in that we can watch the progress of the disease by the x-ray. As a result of intensive occupational studies, where workmen have been kept under observation from the time of entrance into the industry, and over a period of years, it has been possible to measure with a fair degree of accuracy the length of exposure necessary to produce definite silicosis, demonstrable by x-ray, under a given, constant set of conditions.

In the Joplin District, in the old days of dry drilling in the mines, five years' continuous exposure, as a rule, produced definite clinical silicosis with appreciable disability; after tubercle infection was demonstrated, death usually resulted in not longer than two years, and in our series of cases, those who developed silicosis were dead, on the average, ten years after commencing work in the mines. These observations were true for that particular set of conditions. Recently, we had the opportunity of examining over 1,000 films of foundry workers, employed in a group of foundries. Here we found definite cases of silicosis among employees who have been working twenty, thirty, forty years, and even longer in the same foundry, and who were still working at their regular eight-hour shifts. Another set of circumstances produces a clinical picture different from the first example, but constant for itself. Between these two extremes lie many vari-

ations in the clinical picture of silicosis, but these variations differ mostly in intensity rather than in type.

Obviously, the underlying cause of these variations in the intensity of silicosis is the dosage of silica which the individual receives. A very heavy dosage produces disease, disability, and death, more rapidly than a light or medium dosage. The dosage, in turn, is dependent on, first, the amount of free silica in the dust inhaled; second, the quantity of dust in the atmosphere breathed; third, the length of exposure of the individual in terms of months and years, and whether he worked steadily or intermittently.

Actually, in industrial practice, we do find numerous variations in these factors, with much resultant confusion in the ideas of those observers who, conversant with one set of conditions, endeavor to reconcile their findings with published reports dealing with an entirely different set of conditions. Variations among those exposed to an identical hazard may result from abnormalities in the individual, chief among which are pre-existent pulmonary disease and syphilis. The experience at the Picher Clinic indicated that individuals with a 4+ Wassermann contracted silicosis in about one-half the time of normal persons. While this observation has not, I believe, been corroborated elsewhere, I think this is probably because the relationship between silicosis and syphilis has been overlooked.

It is more difficult to make a diagnosis of silicosis, especially in the early stages, in a chance patient encountered in the wards of a metropolitan hospital than when the physician is examining a group of men in an industry and is familiar with the nature and extent of the hazard and with the different occupations of his patients.

Most of our knowledge of silicosis is con-

sequent upon experience gained in the metal mining industry, in which the hazard was severe. (South Africa might well be termed the cradle of our modern experience, followed later by England, the United States, Australia, and Canada.)

The reports emanating from the mining districts in these countries are comparable to a remarkable degree, and the variations in the clinical picture are in direct proportion to the amount of free silica present, modified in later years by the development of protective and preventive regulations. We know a great deal about the symptoms, progress, and prognosis of what Dr. Gardner once called "classical silicosis," resulting from exposure to a moderately or very severe hazard. We are not so well informed with respect to those industries or occupations in which the hazard is less intense, where, we might say, the amount of free silica in the dust ranges from 10 to 25 per cent, and where the quantity of dust is not so excessive. In the former, the clinical picture is clear cut and dramatic and it can't be overlooked, especially if you study it at the point of origin. In the latter, the clinical picture may be indefinite or hazy, so that a diagnosis is made only after a resultant tuberculosis has called attention to the pulmonary condition, or in cases in which one is making routine examinations of groups of apparently well men known to be exposed to some degree of silica dust inhalation. With respect to so-called classical silicosis, the general experience is that, barring accidents, the victims nearly always die of tuberculosis, and the more intense the silica exposure, the sooner does tuberculosis result and the more rapidly does it progress. Statistics of the dusty trades indicate that even when the silica dust hazard is comparatively mild, the tuberculosis mortality is above the average.

The principal and distinctive symptom of silicosis is dyspnea; even in cases in which the exposure is severe, dyspnea comes on insidiously. The silicotic patient, in the early stages of his disease, will tell you that he notices a gradually increasing short wind and a corresponding decrease in

working ability, especially if he is engaged on piece or contract work. He notices an increased tendency to catch cold, and has an irritative, unproductive cough. He looks well and feels well when not exerting himself, and may show a tendency to put on weight. A physical examination at this point will show nothing except, perhaps, weakened breath sounds. His condition may progress to total disability from dyspnea, but usually before that point is reached, especially if the silica exposure has been severe, he lights up a tuberculous infection. When this occurs, one of two things may happen: the change may be sudden and dramatic—the patient seems to go to pieces—loss of weight, fever, night-sweats, copious expectoration, rapid loss of strength, and death in a few months. In other cases, a tuberculous infection progresses slowly and it is sometimes difficult to tell whether or not an advanced silicotic is tuberculous. Usually, the x-ray will give definite information. Moist râles following cough usually indicate infection, but there may be much tuberculous involvement with no bacilli in the sputum and nothing definite on examination.

In advanced silicosis, the dyspnea is extreme. All the accessory muscles of respiration are brought into play in an effort to expand the chest and admit air into the lungs—a demonstration that, once seen, is not forgotten. At the same time, there is no cyanosis, the general appearance may be fairly good, and the stethoscope will give little or no clue to the real condition. Only the x-ray will reveal the structural damage to the pulmonary tissue.

Many silicotics complain of various, and mostly vague, gastro-intestinal symptoms. A considerable number, in our experience, state that they have spit up blood, but true pulmonary hemorrhage is probably not frequent in the absence of tubercle infection. The blood pressure has no particular significance except that it tends to diminish with the progress of tuberculosis. Some cases first become clinically manifest following pneumonia.

The experience of those who have pub-

lished studies in this country and abroad indicates very little in the way of cardiac disease due to silicosis. You do not see large hearts in the x-ray films. Often you do see the small hanging heart associated with tuberculosis. Theoretically, if silicotics do not become infected, they should succumb to right heart failure. Possibly when we have become more familiar with industries or occupations in which the hazard is mild, we may find in men exposed for many years a tendency to disability from heart involvement. However, cer-

tainly all the published reports bear witness to the almost inevitable tuberculous infection.

Prognosis.—Once silicosis is established, the prognosis is bad. The disease tends to progress even after exposure is terminated, and sooner or later infection closes the picture. While occasionally one sees a patient with both silicosis and tuberculosis, living on for years, like an old arrested case of uncomplicated tuberculosis, these are the exceptions. Pneumonia is, naturally, a very serious matter for the silicotic patient.

THE ETIOLOGY OF SILICOSIS¹

By R. R. SAYERS, M.D., Surgeon, and R. R. JONES, M.D., Past Assistant Surgeon, U. S. Public Health Service, Washington, D. C.

THE importance attached to the silicosis problem may be thought of as due to three chief causes: (1) Silica occurs extensively in Nature and is widely used in industry, resulting in the exposure of a large percentage of the industrial population; (2) once silicosis is well established, there is no known treatment capable of restoring normal respiratory function, and in advanced cases there is a definite tendency for them to grow progressively worse, regardless of the measures taken for their relief; (3) individuals suffering from silicosis are particularly susceptible to tuberculosis, so that prevention of silicosis should materially reduce the general morbidity and mortality rates due to pulmonary tuberculosis.

It is an axiomatic principle that accurate knowledge concerning the etiology of any disease is a prerequisite to its effectual prevention, diagnosis, and treatment. A certain amount of general information relative to the pathology resulting from the inhalation of dusts has been in existence since the time of Hippocrates (430 B.C.). Some of the early writers discussed such diseases of the lung under the general term pneumoconiosis. Professor Collis (1), in his 1915 Milroy lectures, furnished us with an excellent historical review of the subject of industrial pneumoconioses. However, it was only late in the nineteenth and early in the twentieth century that clinical and experimental studies were carried out, the results of which have yielded rather definite knowledge concerning the causes of silicosis. Rovida (2), in 1871, used the term silicosis in reporting a case of pneumoconiosis, in which he determined that the condition was due to silica, by chemical examination of the lungs.

According to the committee on Pneumoconiosis of the American Public Health Association (3),

"Silicosis is a disease due to the breathing of air containing free silica. It is characterized anatomically by generalized fibrotic changes and miliary nodulation in both lungs, and clinically by shortness of breath, decreased chest expansion, lessened capacity for work, absence of fever, increased susceptibility to tuberculosis (some or all of which may be present), and by characteristic x-ray findings."

Although other dusts, when inhaled in sufficient concentrations over a long enough period of time, have been shown capable of producing a definite pulmonary fibrosis, nevertheless, the pneumoconiosis characterized by nodular fibrosis has to date been shown clinically and experimentally to be associated only with the inhalation of dusts containing silica. Moreover, it has been established beyond a doubt that exposure to dusts consisting wholly of free silica (quartz) produces this disease, which has not been shown to be the case for any other specific dust. For this reason, the present discussion is limited to the pulmonary fibrosis resulting from the inhalation of free silica dust.

Silica in Nature.—Silica is the most abundant constituent of the minerals and rocks that make up the crust of the earth. It occurs in two forms, free and combined. The free silicas as a group are definite compounds in the form of SiO_2 : the combined forms are spoken of as silicates. Of free silicas which occur in nature, that known as quartz is by far the most common. Quartz is a hard mineral and chemically resistant to reagents; it is an abundant constituent of granite, schist, and other rocks, and the chief component of sandstone and quartzite. Many ores are deposited in veins that consist nearly wholly of quartz. This form of free silica exists in two polymorphous forms, low and high quartz. Low quartz

¹ Read before the Radiological Society of North America, at the Twentieth Annual Meeting, at Memphis, Tenn., Dec. 3-7, 1934.

TABLE I.—OCCUPATIONAL ENVIRONMENT

Uses of Silica	Types of Silica Used
Abrasive uses:	
In scouring and polishing soaps and powders.	Quartz, quartzite, flint, chert, sandstone, sand, tripoli, and diatomaceous earth; all in finely ground state.
In sandpaper.	Quartz, quartzite, flint, sandstone, and sand; coarsely ground and closely sized.
In sand-blast work.	Quartz, quartzite, sandstone, and sand, crushed into sharp angular grains uniform in size.
Metal buffing, burnishing, and polishing.	Ground tripoli and other forms of ground silica.
For sawing and polishing marble, granite, etc.	Sharp, clean sand graded into various sizes.
As whetstones, grindstones, buhrstones, pulpstones, oilstones, etc.	Massive sandstone from very fine to moderately coarse grained.
Tube-mill lining.	Chert, flint, and quartzite in dense, solid blocks.
Lithographers' graining sand.	Medium to fine sand or rather coarsely ground silica and tripoli.
Tube-mill grinding pebbles.	Rounded flint pebbles.
In tooth powders and pastes.	Various forms of pure silica finely ground.
Wood polishing and finishing.	All forms of silica ground to medium fineness.
Refractory uses: In making silica fire brick and other refractories.	Fairly pure quartzite known as gannister; not less than 97 per cent SiO_2 , nor more than 0.40 per cent alkalis, tightly interlocking grains desired.
Metallurgical uses:	
In making silicon, ferrosilicon, and silicon alloys of other metals, such as copper.	Moderately pure sand, massive crystalline quartz, sandstone, quartzite, or chert.
As a flux in smelting basic ores.	Massive quartz and quartzite.
Foundry-mold wash.	Ground sandstone, quartz, and tripoli.
Foundry parting sand.	Fine sand and ground tripoli.
Chemical industries:	
As a lining for acid towers.	Massive quartz or quartzite.
As a filtering medium.	Massive diatomaceous earth and tripoli, sand, finely granular quartz or quartzite, finely ground tripoli, diatomaceous earth, and other forms of silica.
In the manufacture of sodium silicate.	Pure pulverized quartz sand, pure tripoli, and diatomaceous earth.
In the manufacture of carborundum.	Pure quartz sand.
Paint: As an inert extender.	Finely ground crystalline quartz, quartzite, and flint; also finely ground sandstone, sand, and tripoli.
Mineral fillers: As a wood filler.	Finely ground crystalline quartz, quartzite, flint, tripoli, and other types of ground silica.
In fertilizers.	Finely ground silica of all types.
In insecticides.	
As a filler in rubber, hard rubber pressed and molded goods, phonograph records, etc.	Flint, tripoli, and chert, and other amorphous silica preferred; also all other forms of very pure silica, all finely ground.
In road asphalt surfacing mixtures.	Pure quartz sand.
Ceramic uses: In the pottery industry as an ingredient of bodies and glazes.	Very pure massive quartz preferred.
In the manufacture of ordinary glass.	Rock crystal, amethyst, rose quartz, citrine quartz, smoky quartz, chrysoprase, agate, chalcedony, opal, onyx, sardonyx, jasper, etc.
In the manufacture of fused-quartz chemical apparatus, such as tubes, crucibles, and dishes.	Massive and ground diatomaceous earth.
Decorative materials: In the manufacture of gems, crystal balls, table tops, vases, statues, etc.	Do.
Insulation:	
Heat insulation for pipes, boilers, furnaces, kilns, etc.	Moderately pure, sharp, angular sand, preferably finer than 20-mesh, together with a small percentage of finely pulverized silica.
Sound insulation in walls, between floors, etc.	Clear, colorless, flawless rock crystal or massive crystallized quartz.
Structural materials: Sand-lime brick.	
Optical quartz: For the manufacture of lenses and accessories for optical apparatus.	

is stable at temperatures below 573 degrees C., and high quartz is stable between 573 and 870 degrees C. At temperatures below 573 degrees C., high quartz spontaneously

changes to low quartz, so that, practically speaking, distinction between the two classes is of little importance. Probably the next most common form in which free

silica exists in nature is the amorphous hydrated form known as opal ($\text{SiO}_2\text{-H}_2\text{O}$). Opal, which is a silica of colloidal origin and occurs abundantly in the diatomaceous earths, is less resistant to reagents than quartz. Another type of free silica frequently found is flint, and with flint is found chalcedony, a waxy translucent form of silica interpreted as consisting of fibers of quartz with a small amount of interstitial opal. Other forms of free silica occurring less abundantly in nature are tridymite, cristobalite, and siliceous glass or vitreous silica.

Occupational Exposure to Silica.—Owing to the fact that the earth's crust contains so great an amount of silica, it is obvious that those occupations concerned with the driving of tunnels, development of highways, mining, and the like are frequently associated with a silicosis hazard. A second class of occupations exposing the workers to this hazard are those connected with industries that have to do with the processing and industrial use of mineral products, such as the smelting and refining of ores; the use of sand and gravel for structural purposes; the carving of stone, particularly granite; the manufacture and use of abrasives and the processing of the various forms of free silica. According to Knopf (4), the most common forms of free silica used industrially are massive crystalline quartz, quartzite, sandstone, flint, tripoli, diatomaceous earths, and silica sand. Table I, from Ladoo (5), illustrates the great variety of uses to which silica is put in industry, and the kind of silica adapted to each purpose.

In a recent survey (6) carried on in a large manufacturing center, it was found that about 9 per cent of the industrial workers were employed in occupations in which the silica hazard required consideration. According to the census for 1930, there were gainfully employed in the manufacturing and mechanical industries in this country approximately 14,000,000 persons. If the above survey can be accepted as representative of the occupational distribution of these workers, it appears that there are nearly 1,200,000 individuals po-

tentially exposed to a silicosis hazard in the manufacturing and mechanical industries alone. Lanza and Vane (7), in their discussion concerning the prevalence and effect of silicosis, state as follows: "Our very rough, but obviously conservative, estimate of the number of workers exposed to silica dust to a harmful degree in the United States is, therefore, upwards of 500,000."

Factors Influencing the Action of Silica Dust Particles as the Exciting Cause of Silicosis.—Although it has been shown that silica is the exciting cause of silicosis, there are certain factors which must be considered as influencing its action. Early workers were inclined to consider that the injury produced by the dust particle was due to the mechanical irritation produced by its hard and cutting edges. Gardner (8) has shown experimentally that the inhalation of finely divided carborundum dust, of a greater hardness than silica particles, does not produce the nodular reaction characteristic of silicosis. Collis (9) was one of the early workers to draw our attention to the chemical action of dust. Gye and Kettle (10) have shown that silica in solution or non-crystalline form exerts a toxic action upon the tissues which leads to the proliferation of fibroblastic cells. Lately Miller and Sayers (11) have reported results of experimental studies which illustrate clearly the reaction of peritoneal tissues to certain dusts. Only the silica-containing dusts have uniformly produced a proliferative reaction. Other dusts have been either completely absorbed, leaving no scar tissue, or have remained unaltered in the form in which they were injected. These latter reactions are classed as absorptive or inert.

Since dust, to exert its harmful action, must enter the finer divisions of the lung, the particle size of the atmospheric dust bears a definite relationship to the injurious effect produced. The silica must be present in the air in particles small enough to enter the finer air spaces, and of such dimensions that the phagocytic cells may engulf them. From our knowledge of these

TABLE II.—SIZE-FREQUENCY DISTRIBUTION OF VARIOUS INDUSTRIAL DUSTS AS COMPARED TO OUTDOOR DUST

Kind of Dust	Number of Samples	Median	Average Frequency in per cent—Size Group in Microns											
			0 to 0.49	0.5 to 0.99	1.0 to 1.49	1.5 to 1.99	2.0 to 2.49	2.5 to 2.99	3.0 to 3.49	3.5 to 3.99	4.0 to 4.49	4.5 to 4.99	5.0 to 5.49	5.5 to 5.99
Outdoor dust....	179	0.5	56.0	41.0	2.5	0.5	..	..	..	..	..	..	..	..
Sandblasting.....	9	1.4	1.4	19.7	34.7	20.3	12.6	5.2	2.8	1.6	1.1	0.2	0.2	0.2
Granite cutting...	4	1.4	2.0	19.0	33.6	24.5	10.4	4.6	3.1	.6	.9	.3	1.0	..
Trap rock milling:														
Crusher house...	1	1.4	0	13.0	39.0	33.0	10.5	2.5	2.0	..	..	..	..	..
Screen house...	1	1.3	2.0	31.5	33.0	16.0	10.0	4.5	2.5	.5	..	..	..	..
Disk crusher...	1	.9	10.0	48.0	31.0	6.0	3.0	1.0	1.0	..	..	..	..	..
Foundry parting compound.....	2	1.4	0.5	22.0	42.0	17.3	9.2	5.0	1.5	2.0	.5	..	..	..
General foundry air.....	1	1.2	0	26.0	48.0	17.0	8.0	1.0	..	..	..	..	..	..
Talc milling.....	1	1.5	0	16.0	32.0	20.0	13.0	7.0	5.0	2.0	2.0	0	0	1.0
Slate milling.....	1	1.7	1.0	13.0	29.0	17.0	14.0	14.0	6.0	4.0	1.0	0	1.0	..
Marble cutting....	1	1.5	0	12.0	37.0	21.0	10.0	11.0	3.0	0	1.0	2.0	2.0	1.0
Soapstone dust...	2	2.4	1.2	16.0	19.0	13.0	11.0	6.0	6.5	4.5	5.5	3.3	2.5	11.5
Aluminum dust...	1	2.2	3.0	8.0	20.5	14.0	11.5	9.0	6.5	3.0	3.5	4.0	7.0	10.0
Bronze dust.....	1	1.5	1.0	12.0	33.5	25.0	21.0	6.0	1.5	..	..	..	..	..

cells we know that they usually are unable to handle bodies greater than ten microns in their greatest dimensions. The natural defenses of the respiratory tract probably prevent many particles larger than ten microns ever reaching the finer divisions of the lung, and such as do are likely to be expelled with the bronchial secretions. The soluble silica plays a definite part in the production of the disease, and the size of the particle also affects the rate of solution, due to the fact that the smaller the particles the greater the total surface area exposed to the action of solvents.

Table II shows the size distribution of various industrial dusts as compared with the dust particles observed in the outdoor air in the general atmosphere. It is found that about 70 per cent of the particles found in industrial dusts generally are between 0.5 and 3 microns in diameter. Frequently there are, no doubt, many times as many particles too small to count by the method used, but experimentally it has been shown that a great percentage of such sub-microscopic particles are not retained in the lungs but pass out with the expired air. Sayers (12) has shown that less than 15 per cent is retained when the finer particulate matter, such as lead in the form of fumes, is inhaled. The greater majority of

particles found upon microscopic examination of the lung also fall within the limits of from 1 to 3 microns.

Another reason for considering the size of the particles as affecting the harmfulness of the dust, is that it is the larger ones that settle out rapidly while the rate of falling for the smaller particles is very slow. Figure 1 illustrates graphically this difference; those under 1 micron fall (specific gravity, 2 or 3) at a rate of from one to three feet per hour, while a particle of 5 microns in diameter (specific gravity about 7) falls about 60 feet per hour. Particles of more than 10 microns would settle out with relative rapidity. The fact that the finer particles practically remain suspended in the atmosphere for such periods greatly increases their chance of being inhaled.

Thus we may say from the viewpoint of etiology that the harmfulness of a given dust containing free silica is directly influenced by the number of particles it contains of free silica less than 10 microns in diameter, and probably the greatest harm is produced by those between 1 and 3 microns.

The relationship of dust concentration and duration of exposure are closely associated in their etiologic significance. The rate at which silicosis will develop, ex-

cluding certain factors considered as predisposing, depends upon the dosage of free silica. This dosage is obviously dependent

mittent employment as an aid in lessening the amount of changes produced, but aside from the fact that it does delay the reac-

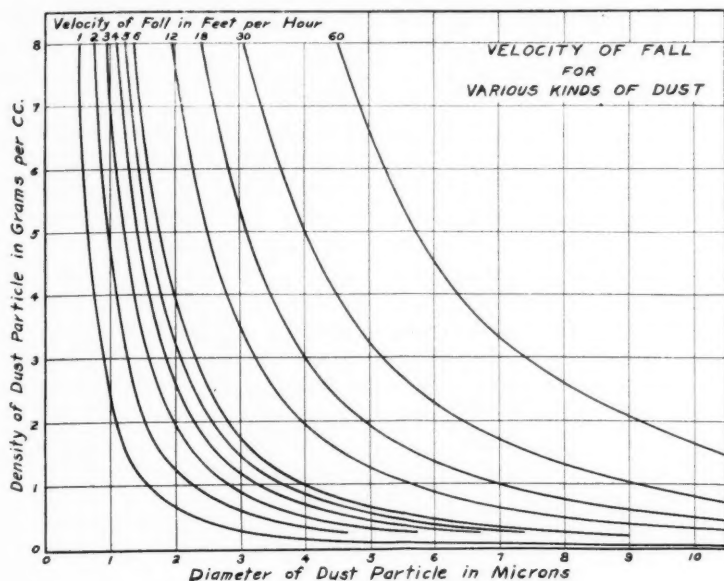


Fig. 1.

upon the amount of silica in the air inhaled, and the duration of exposure.

In 1902, a committee, of which Dr. J. S. Haldane was a member (13), reported upon an investigation made to determine the cause of excessive mortality rates from tuberculosis among the Cornish tin miners. This group decided it was evident that the inhalation of stone dust by these men in the performance of their tasks as miners, was the cause of permanent damage produced upon the lungs. Furthermore, they noted that the condition developed gradually in the case of the ordinary miner, but rapidly in the case of the machine workers who were exposed to greater amounts of dust. Dr. Watkins-Pitchford (14), Dr. Mavrogordato (15), and other South African workers, in their discussions relating to the etiology of silicosis, emphasize the relationship of the concentration of dust and duration of exposure to the degree of lung changes produced. Mavrogordato has suggested the advisability of inter-

tions, it has not been shown that it could safely be relied on to prevent silicosis, in cases in which exposure is to sufficient concentrations. It is intimated that the rest interval allowed by intermittent employment permits the lung to free itself of some of the particles. This avenue of elimination will vary with the types of dust; for example, limestone and coal dust are more readily eliminated than those concentrations with high percentages of free silica. Once the dust is taken up by the cell, the direction of the dust cell in its expulsion from the immediate site of action is toward the lymphatics as well as toward the epithelial lining of the bronchioles, and some portion will be retained. It is admitted that this rest interval will permit the subsidence of the irritative reaction, which no doubt accompanies the inhalation of foreign particles into the finer lung passages. Workers in this country have also shown the relationship of dosage to the severity of the reaction. Reports of the

Picher Clinic (16), of the Tri-State District of Oklahoma, Kansas, and Missouri lead and zinc mines, which is a co-operative undertaking, by agents of the operators, the Metropolitan Life Insurance Company, the Bureau of Mines, and the Public Health Service, have shown clearly the effects of various periods of exposure to silica as met with in the mining processes carried out in the district. Similar studies upon the health of granite workers (17 and 18) likewise stress the duration of exposure necessary to produce definite degrees of silicosis.

Some authors have expressed the opinion that the presence of other inorganic dusts in the silica-containing atmosphere may tend to influence the effects of the silica inhaled. The exact action of these accompanying dusts remains to be determined. Heffernan (19) reported the absence of silicosis among a group of employees in a ganister brick manufacturing establishment, where the material used contained more than 80 per cent silica. However, before we may consider this as evidence that, as he suggests, the presence of other inorganic dusts along with the silica prevented the harmful silica reaction, there are several bits of additional information which must be supplied. First, he did not show that the men were really exposed to harmful concentrations of free silica. In the manufacture of these bricks, the initial step includes the wet mixing of the materials and it is possible that sufficient exhaust ventilation was maintained to prevent the dispersion of free silica into the atmosphere. In fact, Dr. Heffernan states that the atmosphere of the workroom where this process was carried on was quite free from dust. Later operations were of such a nature that much of the free silica which may have been present would become fused or otherwise modified to such an extent that little free silica was available. Laboratory studies to determine the concentration and chemical and physical properties of the dust in the air these men breathed would aid greatly in the scientific interpretation of this report.

Some have thought that the relative

absence of silicosis in the cement industry was due to the calcium present. However, investigations (19) have led to the belief that the absence of evidence of extensive pulmonary fibrosis among employees in the cement industry is due to the fact that there is insufficient total exposure to free silica (considering concentration of dust and duration of exposure) rather than that there is any neutralizing effect due to the calcium.

Again, the various peritoneal reactions to different inorganic dusts, as reported by Miller and Sayers (11), rather definitely suggests that the determining factor responsible for the action of each dust is dependent upon the amount of free silica present and not upon the presence or absence of other dusts.

No complete reports of pulmonary fibrosis resulting from the inhalation of organic dusts have appeared in the literature. Always when such fibrosis is associated with the breathing of air containing organic dust, either inorganic dust has been shown to be present or at least its absence not definitely proved.

In regard to the presence of other irritating dusts, Chapman (20), Kessler (21), MacDonald (22), Kilgore (23), and others have reported cases of so-called acute silicosis, resulting from the inhalation of air containing high concentrations of silica along with strong alkali in a finely powdered form. Some have suggested that the rapid action of the silica in the production of pulmonary fibrosis is aided by the presence of these alkalis, because silica is more soluble in alkaline solutions. Kettle (24) failed to demonstrate such actions experimentally and states that proof is still lacking that any action of the kind may occur. Pathologic reports furnish evidence of a definite fibrosis, but the entire picture differs remarkably from that of the typical silicotic, such as has been furnished by Gardner (25) in his reports upon the examination of tissues from clinical cases of silicosis as well as his pathologic reports made from tissues obtained in his experimental studies. There is need of scientific

research to determine the action of such concentrations of silica alone, as well as the reaction resulting from the inhalation of the alkali in the absence of silica, before the whole truth in regard to these cases will be known.

Sayers, Meriwether, and Lanza (16) reported that, of the employees in the lead and zinc mines, those who gave a history of previous coal mining experience developed a definite silicosis in a shorter time than did employees of the same age without this experience. This cannot be taken to mean, however, that the inhalation of coal dust hastened the action of silica, for it is doubtful if any of these coal miners had worked where they were not exposed to some free silica, so the total dosage of silica was not the same in the two groups.

Occupational History.—A discussion of the total dust exposure and its etiologic significance calls for a few words concerning the occupational history. Table III

TABLE III.—OCCUPATIONAL RECORD

Date: Aug. 8, 1933	Office: Industrial hygiene
Name: K. M.	Present age: 59
Age began work: 15	No. years worked: 41

	Specific occupation	Specific industry	No. years in hard non- coal dusty
Present	Section foreman	Anthracite coal	5
Preced-			
ing			
Present			
1	Contract miner (chamber)	Anthracite coal	15
2	Miners' laborer (chamber)	Anthracite coal	3
3	Mule driver (dry mine)	Anthracite coal	3
4	Patcher (dry mine)	Anthracite coal	2
5	Slate picker (dry breaker)	Anthracite coal	2
6	Farm laborer (Pa.)	Agriculture	1

Remarks: Estimates total time idle during working life, 3 years.

shows how important it is to secure a complete occupational history and suggests a method of recording the same. Were we to examine an individual who states that he is foreman, and try to fit his dust exposure while at such work into the

picture found representing clinically and radiographically that of advanced silicosis, we would be led to think that such mild exposure was harmful, while the complete occupational exposure shows that his true dosage of silica has been very high. Furthermore, by recording complete data, we are able to express his average exposure in terms that may be compared to other cases of similar severity. Again, complete histories sometimes contain suggestive evidence of the true nature of the individual's disability. Especially is this so in those cases in which the worker has been continually changing to jobs requiring less and less physical effort. Table IV shows the

TABLE IV.—ESTIMATION OF THE INDIVIDUAL'S TOTAL DUST EXPOSURE

Occupation	No. Years	Dust Concentration in Millions of particles per Cubic Foot (Average)	Millions of particle-years per Cubic Foot
Slate pickers (dry mine)	2	38	760
Patcher (dry mine)	2	71	142
Mule driver (dry mine)	3	71	213
Miners' laborer (chamber)	3	480	1,440
Contract miner (chamber)	15	480	7,200
Section foreman	5	7	35
Total	30	...	9,790

9,790 millions of particle-years per cubic ft.
30

326 millions of particle-years per cubic ft.

method of analysis used to determine an estimate of the individual's total dust exposure.

More detailed application of our knowledge of the true cause of silicosis is illustrated in Table V. In this study of the actual duties required by the job, it is revealed that the greatest hazard is that in connection with the use of a parting compound. It is obvious that the risk associated with the work the man must do can be materially lessened by either using a parting compound containing less silica, or in properly safeguarding the user by adequate dust control during this operation. With such occupational histories available, and the knowledge of the percentage of total dust exposure revealed by detailed oc-

cupational analysis, it was found possible in a recent study to prophesy approximately in nine cases out of ten the conditions that would be found upon physical examination in cases in which the total changes were due chiefly to dust inhalation.

TABLE V.—DUST EXPOSURE OF MOLDERS

Activity	Time of Exposure in Minutes (a)	Av. Dust Exposure in Millions of Particles per cu. ft. (b)	Millions of Particles-minutes (a × b)
Use of parting compound	54	63.8	3,445
Remaining task in molding	412	4.4	1,813
Pouring	58	3.1	180
Dumping molds (shake out)	16	32.5	620
Total	540	....	6,058
$\frac{6,058 \text{ million particle-minutes}}{540} = 11 \text{ million particles per cubic foot}$			

Predisposing Causes.—The question of predisposing factors relating to the cause of silicosis has been given as much attention as the exciting cause. The part played by race may be disposed of very briefly by saying that it has not been scientifically proved that race itself exerts any influence either upon the production or the retardation of pulmonary fibrosis due to silica. Evidence of the harmful action of silica upon the lung tissues has been demonstrated in every part of the civilized world. From the same line of reasoning, climate, temperature, and related factors may safely be assumed to play no important rôle in the production of silicosis. It is obvious that sex can play no part in a disease of this nature except that the type of industries wherein the silica hazard is found employs relatively few women.

The relationship of age *per se* has not been demonstrated to be of great importance. While certain observers have reported that men past the middle ages may develop silicosis following shorter exposures than younger individuals, the element of infection has not been completely ruled out in such cases. Since respiratory infection has been shown to be the greatest pre-

disposing and complicating factor in the development of silicosis, certainly the history of present and past respiratory infections will have to be given consideration in the statistical analysis of records upon which such conclusions are based.

The factor of individual susceptibility is often mentioned. Generally speaking, if there be any difference in individual susceptibility, it can usually be considered an acquired and not a congenital condition; in this respect it may qualify along with age as a predisposing factor. We may have no clinical or experimental proof, but theoretically, at least, we would expect cardiac abnormalities to reduce the vital capacity of persons manifesting such a condition. Ickert (26) has furnished us a review of the question of personal susceptibility. He quotes Bohme, Lucanus, and Schulte-Tiggs as stating that it is essential for the individual to possess excellent functioning nasal passageways, in order that the self-cleansing mechanism may work efficiently. He calls attention to the fact that Irvine, Simpson, and Strachau report the "classical" type of silicosis to be more common among the robust type of individuals, while the "infective" type is more often observed among the phthisical individuals with less respiratory reserve. Ickert found some slight variation in the susceptibility of persons according to their type of body build. As a whole, the group classed as slender individuals developed simple silicosis somewhat more slowly than the stoutly built persons, but the incidence of advanced silicosis was greater in the former class, being nearly double that developing in the sturdy workers.

Lehmann's (27) experiments to determine the functional efficiency of the upper respiratory tract, in the removal of dust, suggests that abnormalities of the nasal passageways probably play some part in the rapidity with which silicosis may develop. Using dust with a high silica percentage, he found that from 8.3 to 73.7 per cent of the dust was retained during passage of air through the nose. In carrying out this experiment upon 62 miners,

he found that the average retention by the nose in the case of non-silicotics was about 50 per cent, while in the case of miners with silicosis, the average retention was only about 22 per cent.

Chronic bronchial asthma may be considered a predisposing factor affecting individual susceptibility. The spasmodic attacks, if at all frequent, necessarily lead to a reduction in the individual's vital capacity. Aside from the pulmonary fibrosis, other pathologic manifestations of silicosis such as bronchiectasis, emphysema, and right-heart hypertrophy and dilatation, may be aggravated by this chronic condition.

Chronic infections of a local or constitutional nature may be shown to influence materially the incidence of silicosis.

As regards infection in general, Dr. Lanza (28) has stated that in all his experience he can recall seeing but one patient who died of pulmonary fibrosis uncomplicated. The results of the survey in the Tri-State district emphasized the rôle played by infections in disabling silicosis, and mentioned the frequent occurrence of bronchial spirochetosis. Recently, Proske (29) has published reports of additional work along this same line, which should do much to stimulate the taking of preventive measures to control such infections in the sinuses and dental regions, as may serve as a source of these organisms.

Infections developing along the respiratory tract, whether confined to the upper air passageways or involving the bronchi and finer divisions of the lung, are of utmost importance. Sinus infections may act by decreasing the efficiency of the upper respiratory tract in the removal of dust from the air passing to the lungs, and also they may be the source of infections that spread to the lower respiratory tract. Acute pneumonic conditions as well as the more chronic lung changes, such as chronic bronchitis, bronchiectasis and bronchiolectasis, emphysema, and pleurisy, all tend to decrease the ability of the lung to rid itself of foreign materials through lessened lymphatic drainage and decreased power to

force the bronchial secretions and foreign matter from the lungs. When we consider the pathologic changes present in the lungs of individuals suffering from well established or advanced silicosis, we can understand how impossible it would be for such changes to exist for long without the factor of infection becoming evident. The dilated bronchi and areas of emphysema developing in persons as a result of abnormal demands made upon the lungs by glass blowers, divers, professional singers, trumpeters, and the like, seldom advance to the point at which the individual offers any complaint until infection has entered the picture.

Dr. Christie (30), in a recent review and discussion of the subject of bronchiectasis, emphasized the infective element as well as other pathologic changes associated with the condition. The lung changes accompanying silicosis might be expected to lead to conditions favoring bacterial invasion. Some writers, who are most familiar with the problem, believe that the dense areas of fibrosis seen at autopsy or appearing as conglomerate shadows in the x-ray film possibly are dependent upon an infective process, either present before the absorption of silica or developing in an area of pulmonary fibrosis due to the action of the silica.

Tuberculosis and Silicosis.—In 1905, Dr. Summons (31), of the Miners' Phthisis Committee of Australia, reported that gold miners there who contracted silicosis died of tuberculosis. The increased incidence of tuberculosis among occupational groups exposed to silica has been clearly shown in every instance in which this hazard exists. Britten (32) summarized the report of the Registrar-General of England and Wales from 1921 to 1923, and showed the occupational mortality rate for the group of trades classed as "Dusty Trades" to be from three to more than ten times as high as the rate for all occupied and retired males (Table VI).

Lanza and Vane (7) show, by an analysis of the mortality experience of twelve life insurance companies, for the period of

TABLE VI.—STANDARDIZED MORTALITY FROM RESPIRATORY TUBERCULOSIS IN OCCUPATIONS WITH RATES ABOVE AVERAGE (Males aged 20 to 65 years, from 1921 to 1923, England and Wales)

Occupation	Mortality Rate (standardized)
All occupied and retired males	149.6
Tin and copper mines, underground workers not superintending staff (III)	1,886.0
Tin and copper mines, not superintending staff (III)	1,323.5
Grinders in the cutlery tools (IV)	1,178.5
Metal grinders (IV)	636.7
Slate masons and slate workers (III)	512.5
Potters' mill workers; slip makers; potters (III)	411.4

1915 to 1926, that the actual mortality from respiratory tuberculosis among the silica-exposed persons was about three times that of a non-silica exposed group. When this comparison is limited to the rates for some of the occupations with a very great silica exposure, such as metal mining, sandstone and granite quarries, the excess is still more striking, the rate being about ten times that obtained in the non-silica exposed group.

The initial studies of silicosis by workers in South Africa were started by a demand made upon the health authorities to determine the cause of the excessive mortality from tuberculosis which was increasing at a rapid rate among the gold miners there. The study by Russell and others (17) of the health of the granite workers was prompted in part by the excessive number of deaths reported as due to tuberculosis in the section of Vermont in which the granite industry is located.

Gardner's (33) statement that "At least 75 per cent of those human beings who develop silicosis die of tuberculosis, which may make its appearance at any stage of the disease," stresses the importance of the silicosis problem from the viewpoint of anti-tuberculosis activities. Rist and Donbron (34) advance the theory that there is no nodular fibrosis until the element of infection has entered the picture. Such a theory, however, does not agree with experimental work, which has shown that

the nodules may be produced in the absence of evidence of infection.

Kettle (35), Price (36), and others have shown that the tubercle bacillus will grow more rapidly upon culture media to which a small amount of silica offers a favorable medium for the growth of the organism. Gardner (37) has shown that animals exposed to silica, when inoculated with a strain of tubercle bacilli of low virulence will develop systemic tuberculosis and die, while control animals not so exposed usually are not seriously affected by injections of such organisms.

Progressive Tendency of the Disease.—Since infection has been shown to play so important a rôle in the advanced stages of the disease, the possible relationship of this infective element to the progressive tendency of the disease cannot be overlooked.

Irvine (38) has stated that it is not so much what the condition of the silicotic is to-day, as what it will become to-morrow. He emphasizes the tendency of the fibrosis to progress even though removed from exposure, and expresses his opinion that it is one of the most serious aspects of the whole silicosis problem. No remedy has been shown to be of value in elimination of the pulmonary fibrosis, although certain improvement in symptoms may be noted after the victim is removed from exposure. According to the observations made by Bohme-Bochum (39), silicosis progressed, after removal from exposure, in 20 per cent of the cases diagnosed as having silicosis Grade I; in 40 per cent of the cases in Grade II, and in practically all cases in Grade III. The course of silicosis among workers no longer exposed to silica dust is adequately stressed in the report of Russell (17), and the references discussed furnish evidence that regardless of termination of exposure, silicotics may eventually progress to a more severe and even fatal condition. Such reports from workers most familiar with the condition surely serve to emphasize the seriousness of this occupational disease.

In concluding, it may be stated that, to understand fully the true etiologic factors

accounting for the development of silicosis in a single instance, requires detailed knowledge of the individual's occupational exposure past and present, together with facts obtained through a complete physical examination. Particular attention must be given to positive evidence of old or recent respiratory infection. Although slight mention may be made of the predisposing cause, after all, in the great majority of cases, whether individuals will develop silicosis depends almost entirely upon the concentration of free silica particles under 10 microns in diameter to which they may be exposed and the duration of such exposure.

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FURTHER OBSERVATIONS ON THE ROENTGEN DIAGNOSIS OF CORONARY DISEASE¹

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ACCORDING to statistics taken from some of the large life insurance companies, coronary disease is one of the most common causes of death. Moreover, the incidence of death from coronary disease shows a progressive and actual rise.

clinical, and necropsy investigations by a large number of observers. Since then, experience gained in the study of numerous additional cases together with confirmatory observations in other clinics have strengthened the reliability of the signs and

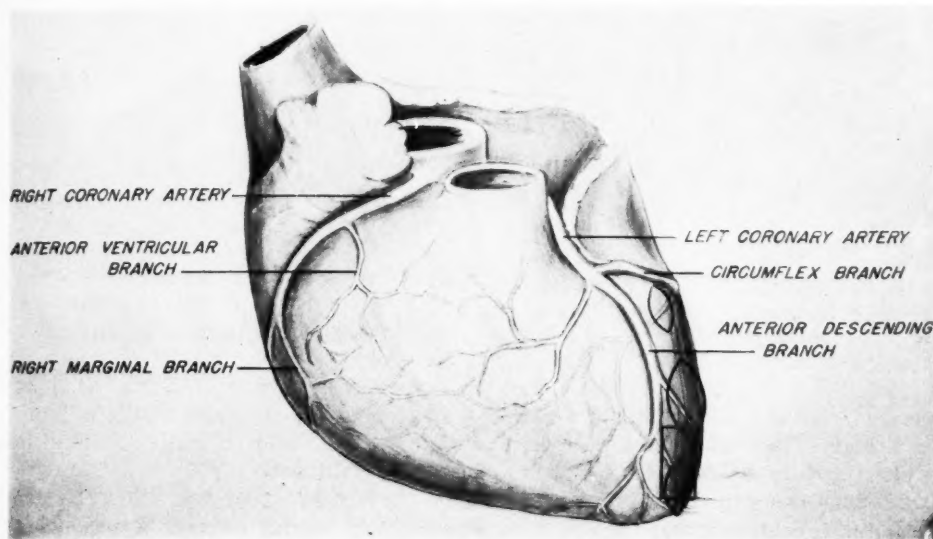


Fig. 1. The coronary arteries (after Cunningham) showing most common sites of infarction. The rectangle represents thrombosis of the anterior descending branch; the ellipses represent the circumflex branch.

For example, among the industrial policy holders of the Metropolitan Life Insurance Company, deaths from coronary disease increased 200 per cent in 1933 as compared with 1930 (1, 2). It is, therefore, obvious that every diagnostic aid must be invoked for the earlier recognition of this very common and serious affliction.

In a previous communication (3) on the roentgenologic signs of coronary disease we described diagnostic criteria based upon known physiologic and pathologic changes accruing from a multiplicity of laboratory,

yielded additional information useful in the roentgenologic diagnosis and observation of coronary disease.

ANATOMICAL AND PATHOLOGICAL CONSIDERATIONS

The coronary arteries (4) arise from the aorta: the right from the anterior aortic sinus and the left from the posterior aortic sinus (Fig. 1). The right coronary artery runs between the root of the pulmonary artery and the right auricle to the coronary sulcus, in which it passes to the right, giving off an anterior ventricular branch; then, turning round the right border of the heart, is continued on its posterior surface, where

¹Presented before the Fifth International Congress of Radiology, Chicago, Sept. 13-17, 1937.

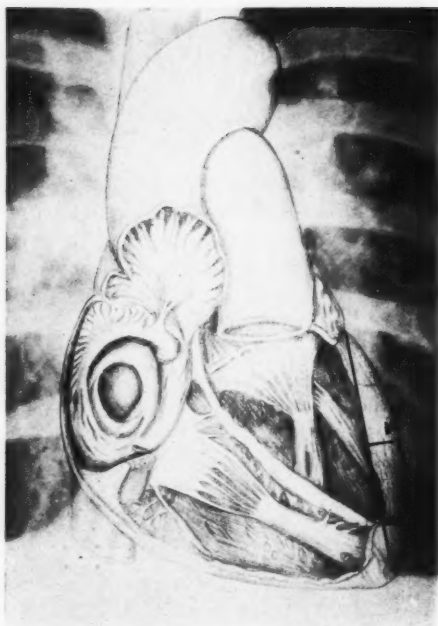


Fig. 2. The thickness of the left ventricle is measured by a perpendicular from the point of greatest salience of the left ventricle (arrow) to a line joining the apex and auriculo-ventricular sulcus.

it ends by anastomosing with the circumflex branch of the left coronary. The left coronary artery arises from the posterior aortic sinus and runs between the root of the pulmonary artery and the left auricle to the coronary sulcus at the upper end of the interventricular groove, where it divides into two branches: an anterior descending branch, which runs down the interventricular sulcus to the apex supplying both ventricles; a posterior circumflex branch, which turns round the left margin of the heart and continues to its inferior surface, where it ends by anastomosing with the terminal arborizations of the right coronary. The circumflex branch supplies the left margin of the heart and the posterior part of the inferior surface of the left ventricle.

The left coronary artery is much more commonly involved than the right (5, 6, 7, 8, 9, 10, 11). Interesting anatomical evidence has been produced by Whitten (10) and Boyd (5), who have both shown that

thrombosis of the anterior descending branch most commonly involves the apex and the lower half of the anterior surface of the left ventricle, the anterior part of the interventricular septum and the papillary muscles of the left ventricle.

The circumflex branch ranks second in incidence as the site of thrombosis. It involves the obtuse margin of the left ventricle, half way from base to apex, but sometimes also the base and the apex. These changes are shown topographically in Figure 1. It becomes apparent that the vessels most commonly thrombosed involve that portion of the heart which contributes to the formation of its left border as seen in the roentgenogram.

It has been shown (12, 13, 14) that the thickness of the left ventricular myocardium can readily be determined from the roentgenogram of the heart (Fig. 2). A line is drawn connecting the apex of the heart with the auriculo-ventricular junction on the left. To this is erected a perpendicular from the point of greatest salience of the left ventricular contour. This perpendicular (bisector) is a close approximation to the thickness of the wall of the left ventricle and normally measures from 8 to 10 millimeters.

The thickness of the left ventricle as measured by its bisector is produced by two factors: first, the actual amount of heart muscle present; second, the tone of that muscle. Other factors being equal, if the tone of the myocardium is increased, there is a shortening and thickening of the muscle fibers; if there is a diminution of tone, there is a lengthening and relaxation of muscle fibers reducing the thickness of the myocardium.

Coronary disease is insidious in its onset. There is at first an endarteritis involving the intima. Later the middle and external coats become involved. Thus there is a gradual occlusion of the vessel, resulting in a diminished blood supply to the area of distribution of the involved vessel. The degree of occlusion may be variable. If the degree of thrombosis is complete, an anemic infarct is produced, over which the surface

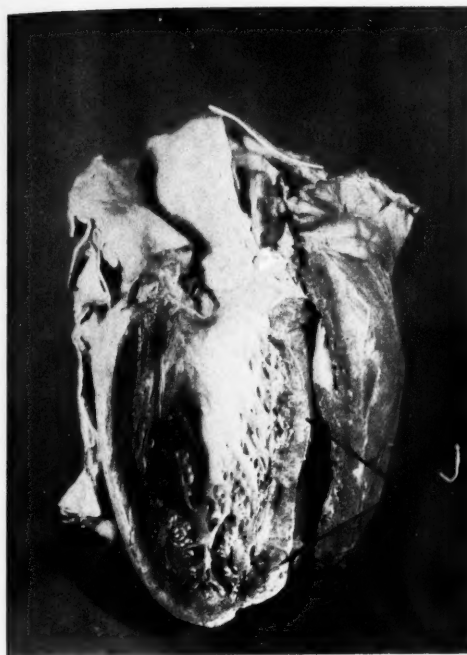


Fig. 3. Coronary thrombosis, with infarction in the wall of the left ventricle (sectioned). Note flattening of the left ventricular myocardium in the region included in brackets.

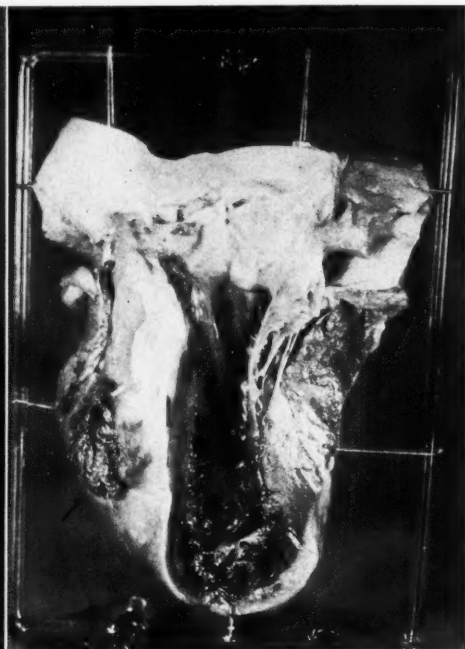


Fig. 4. Cardiac aneurysm following coronary infarction. Arrow points to aneurysm.

of the myocardium is retracted (Fig. 3). Subsequently this area undergoes fibrosis. Occasionally there may be absorption of the infarct, leaving the myocardium thin and bulging and predisposing to the formation of a cardiac aneurysm (Fig. 4). Whitten (10) has shown that there is a marked thinning of the ventricular wall due to occlusion of a large vessel and that a localized depression on the surface of the heart is produced by occlusion of a small vessel coming off at right-angles.

As the blood supply to a portion of the heart muscle is shut off by occlusion of its main source, a collateral circulation is established which ultimately may carry on more or less effectually the task of supplying blood to the area formerly nourished by the thrombosed vessel.

ROENTGENOLOGIC SIGNS

The changes upon which roentgenologic diagnosis of coronary disease depends are

derived from careful roentgenoscopic study as well as examination of the film. A roentgenkymogram (15, 16) also records useful data, particularly if the course of the case under treatment is to be followed, but by far the most important element in diagnosis is careful roentgenoscopic examination.

On the screen we see a definite diminution in the amplitude and force of contraction in the region of the left ventricle. The diminished force may be observed over the entire border of the ventricle or it may be more pronounced in one portion of the left border. In appraising this change it is necessary to make careful comparison of the force of the beat of the involved area with the apex, the left auricle, the right border, and the aorta. In this manner, the degree of diminution of the left ventricular force is readily perceived; for, in the normal heart, the excursion of the left ventricular contractions is greater than in other regions of



Fig. 5. Coronary thrombosis showing the typical loss of convexity of the left border. Roentgenoscopically there is a localized diminution in the amplitude of ventricular contractions.

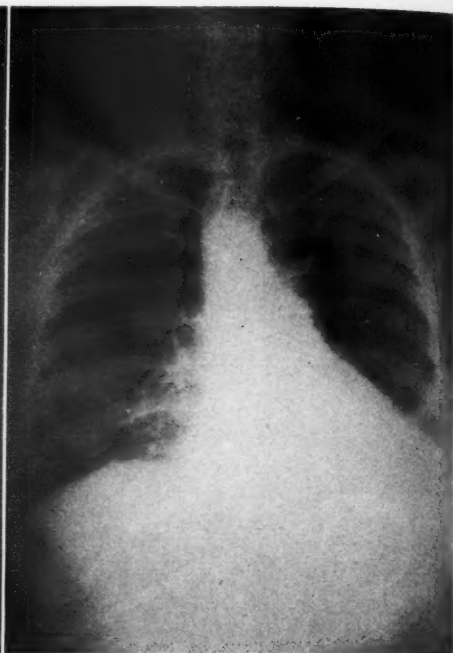


Fig. 6. Coronary thrombosis. The heart appears to "sag." The amplitude of ventricular contractions is greatly diminished.

the cardio-vascular silhouette. Frequently, the change may be emphasized by examination during deep inspiration which not only permits of better visualization of the cardiac apex but accentuates the difference in intensity of beat of component elements of the cardio-vascular shadow. It is also frequently helpful to turn the patient a few degrees in the right and left anterior oblique positions. This brings into profile the right and left ventricles, respectively, and tends to eliminate a confusing factor of motion transmitted from the unaffected adjacent heart muscle. It may be predicated as axiomatic that a *localized diminution in the amplitude or force of left ventricular contractions is due to myocardial impairment*. Not all myocardial impairment, however, is due to coronary thrombosis. It is frequently necessary to exclude other causes of myocardial damage, such as rheumatic myocarditis, hypertensive failure, and depleting constitutional mala-

dies. While it has been our custom to make a roentgen cardiac diagnosis without previous knowledge of the history or physical findings in the case, it may frequently be necessary or expedient to render an opinion after clinical consultation.

Roentgenograms usually show typical alteration in the contour of the heart (Fig. 5). This consists of a loss of convexity of the left border. The left border may become straight or concave. The degree and extent of change depend upon several factors: the acuteness and severity of infarction, the condition of the myocardium prior to the accident, and the degree of broken compensation resulting from thrombosis (Figs. 6, 7).

There is a common misconception even among cardiologists, that the heart is always enlarged in coronary thrombosis. This is not true. While such a change does occur, it is not necessarily present. We have examined cases of coronary throm-



Fig. 7. Coronary infarction with aneurysm (arrow) of left ventricle. The heart contour is typical of coronary disease.



Fig. 8. Kymogram of heart in coronary thrombosis. Note the marked diminution in the amplitude of ventricular contractions in area included in brackets.

bosis, even in the acute stage, in which cardiac enlargement could not be demonstrated by any known method.

Bearing in mind the pathologic physiology of coronary disease, the roentgenologic changes are readily understood. The loss of convexity or sagging of the left border result first, from a loss of tone, and second, from an actual destruction of muscle fibers. The thickness of the left ventricle as measured by its bisector is reduced and the left and right median diameters lie close to the diaphragm.

A roentgen kymogram of the heart will show a localized diminution in the amplitude of ventricular contractions (Fig. 8). It must be remembered, however, that the usual horizontal slit kymogram records only lateral excursion of the heart and that the vertical component of motion is not registered. It is therefore unwise to attempt a diagnosis of coronary disease without roentgenoscopic examination. Per-

haps the principal usefulness of the kymogram is to record what is observed on the screen and to afford a better basis for comparison of subsequent examinations of the case under treatment.

CORONARY SCLEROSIS

Gradual narrowing of one or more coronary arteries with atheromatous degeneration may be a local manifestation of a generalized vascular sclerosis. In such cases there may be visible evidence of sclerosis in the thoracic or abdominal aorta, the internal iliac, or peripheral arteries. Here one does not observe changes of so marked a degree as in coronary thrombosis (Fig. 9). There may be little, if any, change in the contour of the heart. As a rule, the heart will probably be small unless there is an associated hypertension. Roentgenoscopically, the amplitude of ventricular contractions is diminished, but not to such a degree as is found in complete



Fig. 9. Coronary sclerosis. There is no alteration in cardiac contour. There is a generalized but slight diminution in the amplitude of contractions.

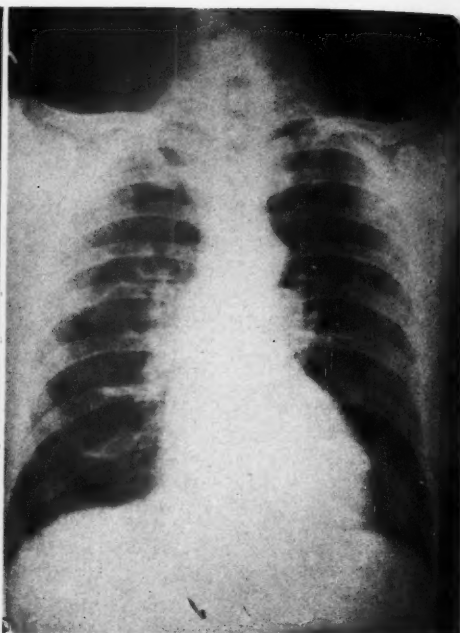


Fig. 10. The heart in hypertension shows hypertrophy with variable dilatation of the left ventricle. Note its smooth, rounded contour. The curve of the ascending aorta is accentuated. Roentgenoscopically the amplitude of contractions is increased in the region of the ventricle and aorta.

occlusion; and the diminished amplitude is *not* pronounced in any particular segment of the cardiac silhouette—there is a general, moderate diminution.

CORONARY THROMBOSIS AND HYPERTENSION

The association of coronary thrombosis and hypertension is by no means uncommon. As a general rule, it is unusual to find coronary thrombosis in women who have not had hypertension. This does not hold true in men (17).

The effect of chronic hypertension is to produce definite alterations in the size, contour, and roentgenoscopic appearance of the heart. Because of the increased peripheral resistance there is dilatation of the left ventricle and hypertrophy of its wall (Fig. 10). Roentgenoscopically one observes an increase in the amplitude of ventricular contractions, together with increased pulsations of the aorta. With the advent of coronary thrombosis and infarction

in the wall of the ventricle, alterations of contour are produced (Fig. 11). The left heart border shows a flattening at the site of the involved myocardium. Roentgenoscopically, the amplitude of contractions in this area is definitely diminished.

CORONARY THROMBOSIS AND CARDIAC ENLARGEMENT

Patients who have not had previous disease of the heart need not necessarily show cardiac enlargement with thrombosis. We have seen clinicians doubt the existence of coronary thrombosis, even in the presence of almost every classical sign and symptom, merely because the heart was not enlarged. This misconception not only militates against early diagnosis but detracts from the importance of cardiac enlargement as a prognostic sign when it is present.

Let us assume that the patient has had no previous heart disease and that he de-

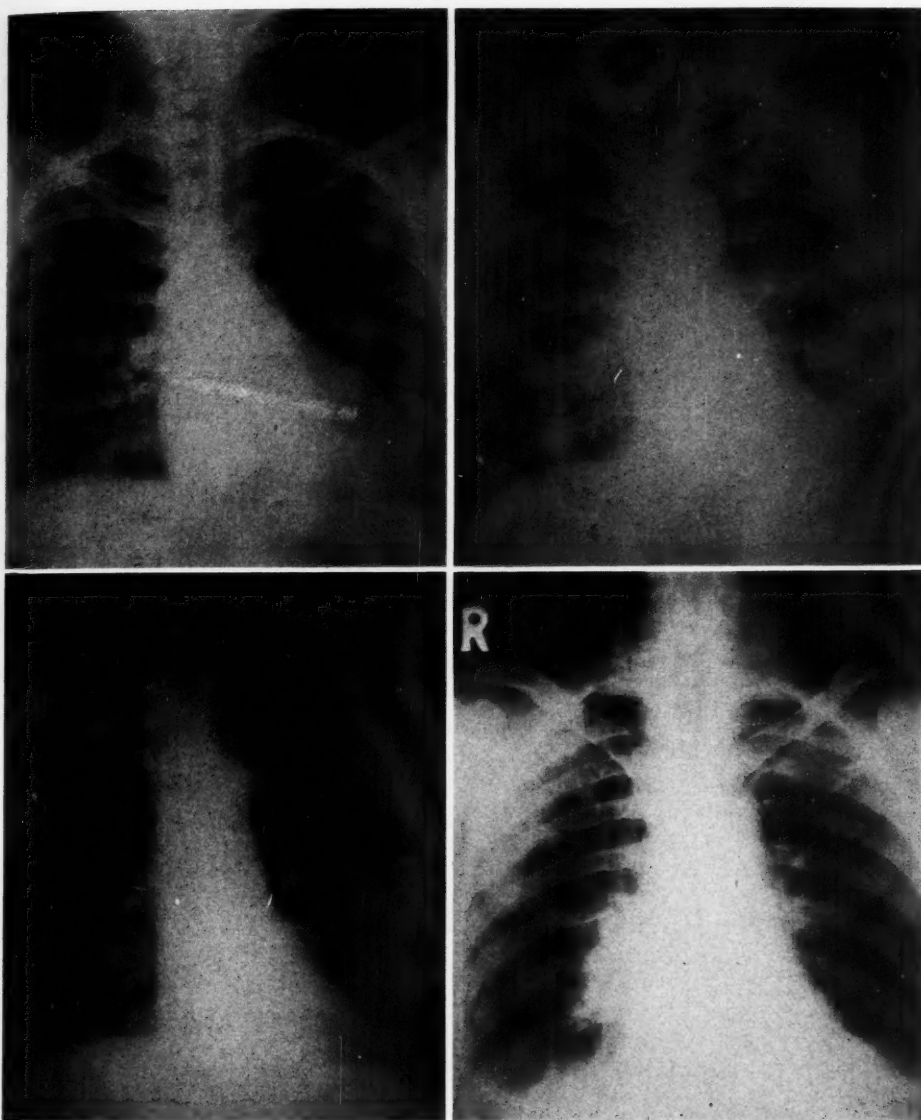


Fig. 11 (*upper left*). Coronary thrombosis with infarction following hypertension. Note the marked flattening of the left ventricle (bracket) as compared with Figure 10. The flattened area showed a marked diminution in the amplitude of contractions.

Fig. 12 (*upper right*). Coronary thrombosis showing typical loss of convexity of left border. The amplitude of ventricular contractions was decreased. Compare with Figure 13.

Fig. 13 (*lower left*). Same case as Figure 12, one month later. Note partial restoration of contour due to recovery of tone. Note also that the heart as a whole was not enlarged.

Fig. 14 (*lower right*). Coronary thrombosis with failure. There is a loss of convexity of the left border, with an increase in the transverse diameter of the heart and congestive infiltration in the lungs. These changes indicate progressive myocardial weakening.

velops acute coronary thrombosis. In such a case there is a very sudden alteration of cardiac dynamics. The acutely embar-

rassed heart-muscle is unprepared and unequal to the strain of contracting properly with an important avenue of blood supply

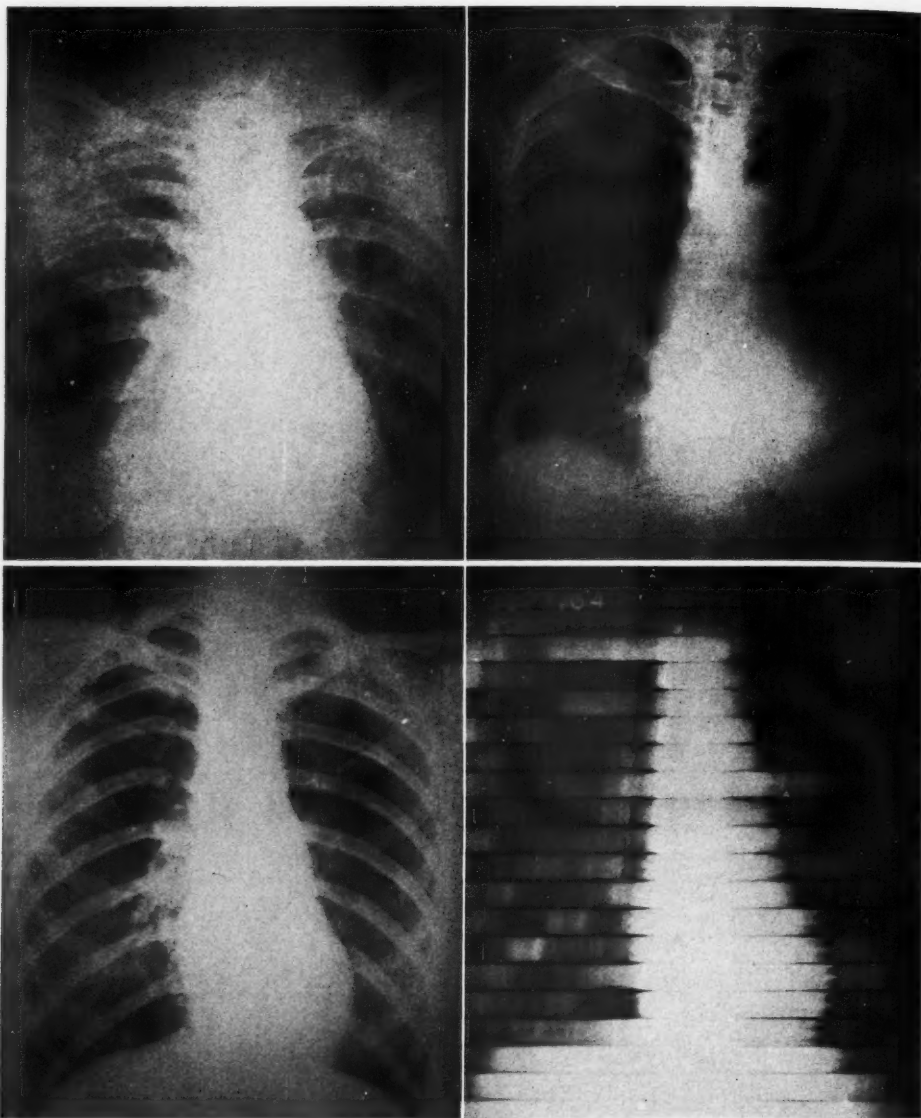


Fig. 15 (*upper left*). Aortic insufficiency may be a cause of anginal attacks. Note the marked increase in the length of the heart due to dilatation of the left ventricle. Typical "water-hammer" pulsations are observed roentgenoscopically.

Fig. 16 (*upper right*). Aortic stenosis. Note the marked hypertrophy of the left ventricle. Ventricular contractions are slow and vigorous, while the amplitude of aortic pulsations is diminished.

Fig. 17 (*lower left*). The heart in thyrotoxicosis shows a loss of convexity of the left border which sometimes simulates the appearance of coronary disease. However, there is usually an increased prominence of the pulmonary artery and the amplitude of pulsations is greatly increased (see Fig. 18).

Fig. 18 (*lower right*). Kymogram of the heart in thyrotoxicosis (same case as Figure 17). The type of pulsations is distinctive.

shut off—and so it relaxes. As the left ventricle relaxes the mitral ring is stretched and a relative mitral insufficiency develops.

At this time, there is an increase in the transverse diameter of the heart and one can detect a systolic murmur at the apex—

evidence of mitral insufficiency. However, if the process of occlusion is gradual, there is usually a more or less adequate collateral circulation and the heart does not relax so completely as to allow stretching of the mitral ring. There is no increase in transverse diameter of the heart and no murmur may be elicited at the apex. If this patient is kept under observation it may be found that there is functional recovery in three or four weeks and the patient may return to modified physical activity (Figs. 12 and 13); or the x-ray may show an increase in the transverse diameter of the heart. This is evidence of a relative mitral insufficiency due to relaxation of the left ventricle and should be regarded as a sign of impending failure. The lungs will usually show congestive infiltration (Fig. 14). If the patient is allowed unrestricted activity, serious sequelae may be anticipated.

DIFFERENTIAL DIAGNOSIS

The symptom-complex of coronary thrombosis may be confused with other cardiac and non-cardiac conditions. Complete roentgenologic examination is at least as well suited to differentiate these as any other single means at our disposal.

It is a strange fact, perhaps common experience in large roentgenologic clinics, how frequently we discover coronary disease in patients who are referred for x-ray examination of the gastro-intestinal tract, the gall bladder, or, even, the left shoulder, because of symptoms referable to these areas and, frequently, coronary disease is the only cause of these symptoms. The roentgenologist who always explores the thorax in every gastro-intestinal examination is thus in position to detect previously unsuspected coronary disease.

ANGINA PECTORIS

While angina pectoris is related to coronary thrombosis the conditions are not identical. The latter signifies occlusion of the coronary arteries; the former is a clinical syndrome of pain, usually at the sternum, shortness of breath, and a sense of impending death. It is frequently possible

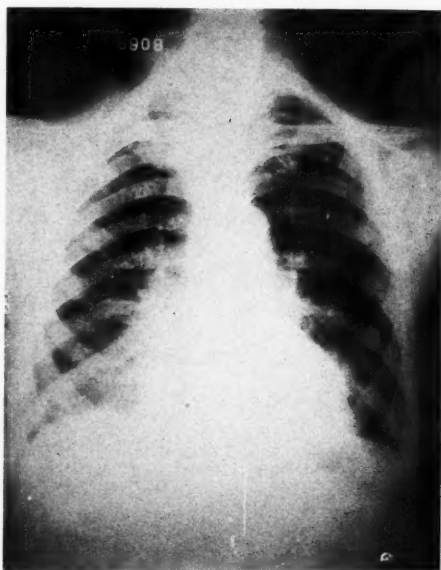


Fig. 19. Anginal attacks may be observed in chronic blood dyscrasias. Frequently there is dilatation of the heart. The above is a case of severe macrocytic anemia. There is a slight, but general, diminution in the amplitude of cardiac contractions.

to detect an etiologic factor in the production of angina pectoris in the form of diabetes, aortic valvular disease, hyperthyroidism, and chronic anemias. Some of the latter present typical roentgen findings which assist in their ready identification.

Aortic insufficiency (Fig. 15) shows a dilated left ventricle so that there is always an increase in length and frequently in the transverse diameter of the heart. The aorta is usually widened. Roentgenoscopically, one observes the typical "water-hammer" pulse—a slow systolic movement of the ventricle and aorta, with a rapid diastolic movement in the opposite direction.

Aortic stenosis presents enlargement of the left ventricle consisting of dilatation of the chamber and considerable hypertrophy of its wall as shown by its bisector (Fig. 16). Roentgenoscopically, one observes a slow, vigorous contraction of the left ventricle with diminished amplitude of aortic pulsations. In advanced cases, calcification of the aortic valve may be seen.

Thyrocardiac disease shows a loss of convexity of the left heart border, with an



Fig. 20. Angina pectoris shows no alteration of cardiac contour or size unless there is an associated cardiopathy.

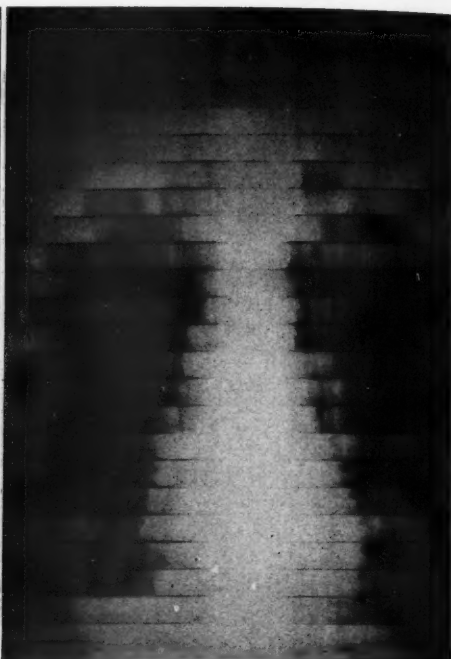


Fig. 21. The amplitude of contractions in angina pectoris is not diminished; it may be increased. (Same case as Figure 20.)

increased prominence of the shadow of the pulmonary artery (Fig. 17). At times, the appearance may be not unlike that observed in coronary thrombosis. In the former, however, there is an accelerated rate with an increased amplitude of pulsations (Fig. 18).

Anemias and chronic metabolic disorders almost always show moderate cardiac dilatation without hypertrophy (Fig. 19). There is only slight, but general, diminution in the amplitude of contractions.

It might be well to emphasize that angina pectoris usually accompanies effort—frequently walking, eating or some other physical or emotional strain—so that generally speaking, pain in the chest which appears when the patient is at rest has another etiologic basis.

Unless there is an associated cardiopathy, the heart in angina pectoris shows no alteration in size or contour (Fig. 20). Roentgenoscopically, the amplitude of pul-

sations is normal, or may even be increased (Fig. 21). Diagnosis, therefore, resolves itself to the exclusion or identification of organic heart disease, in the absence of which the heart contour will appear normal, the presence of normal contractions, and the history. With the advent of coronary thrombosis the roentgenologic manifestations of the latter will be in evidence.

We shall not attempt to present, at this stage, a statistical analysis of our studies. While the series includes several hundred cases, in only a comparatively small number have we had the opportunity for necropsy. It is hoped that others will be stimulated to report their cases so that final proof of the value of roentgenologic diagnosis of coronary disease may be established. We have, nevertheless, been highly encouraged by the findings in those cases that have come to autopsy and by confirmation by other clinical methods and the progress of cases examined.

SUMMARY AND CONCLUSIONS

Coronary disease is one of the most common causes of death. Roentgenologic study is an important additional means of diagnosis.

The typical case of coronary thrombosis shows an alteration in the contour and contractions of the heart. There is a loss of convexity of the left heart border, with diminished amplitude of pulsations in this area. The appearance of an increase in the size of the heart in coronary thrombosis is an indication of failure. Cases of chronic hypertension that develop coronary thrombosis show hypertrophy of the left ventricle, with an area of localized flattening. In this region the amplitude of contractions is definitely diminished.

Coronary sclerosis produces a moderate but general diminution in the amplitude of cardiac contractions, with no alteration of contour.

Angina pectoris presents no alteration in cardiac contour or size unless there is an associated cardiopathy. The amplitude of contractions is not impaired, but frequently is typical of the associated lesion.

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THE ABSORPTION OF ETHYLENE GAS FOLLOWING ENCEPHALOGRAPHY, WITH A CLINICAL CORRELATION IN 164 CASES

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THE roentgenographic follow-up in the study of encephalography with the use of ethylene gas (1, 2) has been of great interest. In certain patients the ethylene has disappeared at an unusually slow rate when compared with that at which the gas disappears in the great majority of cases. This report deals with the estimation of the rate of disappearance of the gas, the interpretation of this phenomenon, and its correlation with the clinical data, especially in those patients in whom the gas disappeared with unusual slowness.

Method.—Single horizontal transverse projections with the occiput down, tube to the side, have proved to be the most valuable views in estimating the rate of disappearance of the gas from the ventricles and subarachnoid spaces following encephalography. This projection is most likely to show any gas that remains. It permits a demonstration of both lateral ventricles and the third ventricle in their long axes and, in addition, demonstrates to the best advantage subarachnoid gas in the basal cisterns and over the frontal cortex. From a series of such views, taken at successive periods following the injection, a roughly accurate estimate of the rate of disappearance of the gas may be made. Early in this study a series of follow-up views was taken in this manner after each encephalogram to establish as closely as possible the rate of disappearance of ethylene. Later, single projections taken three hours after the injection of the gas served to demonstrate whether the rate of disappearance was normal or delayed. If delayed, subsequent films were taken to follow more closely the rate of disappearance of the gas. In each case the estimate was based upon a comparison with the original transverse projection, the second view ordinarily taken in the encephalographic series (1). In this view

the filling was arbitrarily taken as 100 per cent, and the fillings in subsequent films were estimated on a percentage basis in reference to this original view. In this fashion repeated estimates of the same film have shown that this method is almost always accurate within 10 per cent and usually within 5 per cent. On such a percentage basis and within limits which will be considered later a comparison may be made between the relative rates of disappearance of ethylene following its encephalographic injection in different patients.

Interpretation.—A study of the follow-up roentgenograms in 164 patients shows that in a large majority of cases the ethylene gas disappears within certain time limits and that in the remainder the rate of disappearance is slower. A curve representing the lower limits of what may be termed "normal" absorption was established on the basis of the most delayed estimates, in the numerous determinations made in this series, in which the patients were judged, from their encephalographic and clinical findings, to possess a "normal" circulation of cerebrospinal fluid (see Fig. 1). Although individual curves of the rate of absorption of ethylene could not be determined on the basis of the few follow-up views that were obtained in those patients in whom the rate of disappearance seemed retarded, their gross deviation from the usual "normal" rate was nevertheless very obvious.

The establishment of the curve defining the lower limits of the "normal" rate of absorption of ethylene following encephalography was selected arbitrarily, of necessity, as were the criteria of "normal" circulation of cerebrospinal fluid. May it then be concluded that a delayed disappearance of the gas necessarily implies an abnormal condition—presumably a patho-

logical process in the absorptive mechanism?

The factors involved in the disappearance of ethylene or other gases from the

4. The pressure and temperature of the system.

As applied to the conditions involved in the absorption of ethylene following its

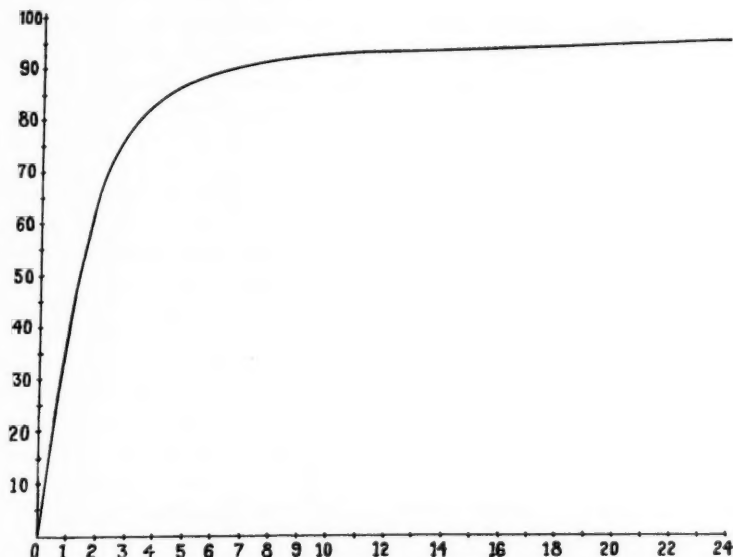


Fig. 1. Curve representing the estimated lower limits of the "normal" rate of absorption of ethylene gas following its encephalographic injection. The time in hours is indicated on the abscissa and the estimated percentage absorption of ethylene on the ordinate.

ventricles and subarachnoid spaces are undoubtedly numerous. The fact that the rate of disappearance closely corresponds to the solubility of the various gases indicates that solubility is perhaps the most important single factor. The comparative rates of disappearance of ethylene, nitrous oxide, oxygen, and air have been estimated in previous experimental work (2). When variations of the rate of disappearance for the same gas are considered, however, the explanation is not so obvious.

The factors known to affect the rate of absorption of a gas by a fluid may be listed as follows:

1. The rate of exchange of fluid.
2. The relative volumes of gas and fluid.
3. The surface contact area between gas and fluid.

encephalographic injection these factors would be:

1. The rate of formation and absorption of cerebrospinal fluid.
2. The volume of ethylene and cerebrospinal fluid exchanged and the estimated volume of cerebrospinal fluid not drained in the process of encephalography.
3. The area of surface contact between the ethylene and the cerebrospinal fluid as determined by the spatial characteristics of the ventricular and subarachnoid spaces.
4. The cerebrospinal fluid pressure. Body temperature.

These factors will be further considered, individually, in the order listed.

1. Since the amount of a gas which may go into solution rapidly diminishes as the

degree of saturation of the solvent rises, it seems safe to conclude that the factors altering the formation, circulation, and absorption of cerebrospinal fluid are probably the most important in determining the variation in the rate of disappearance of the gas. Inasmuch as obstructions to the circulation and absorption of cerebrospinal fluid are commonly attended by clinical manifestations and varying degrees of hydrocephalus, the determination of this point is always of great importance. If the obstruction is considerable, the diagnosis is readily made on the basis of large ventricles accompanied by large subarachnoid spaces (communicating hydrocephalus) or obliterated subarachnoid spaces (adhesions) over the cerebral cortex. In such advanced cases, with associated clinical signs and symptoms of increased intracranial pressure, ventriculography is preferred to encephalography. In many cases, however, as will be shown, the diagnosis is not so clear. If, following encephalography in this group, observation on the rate of disappearance of the gas could be correlated with the formation, circulation, and absorption of the cerebrospinal fluid, such additional information might be of great value in corroborating or clarifying the usual static interpretation of encephalograms. Such a correlation as this would be possible only if the other factors concerned with the absorption of the gas could be shown to be negligible or relatively constant.

2. In certain cases an abnormally large amount of cerebrospinal fluid may be present in the ventricles and subarachnoid spaces. Consequently, the gas injected would bear a variable relationship in its ratio to the total fluid present and its absorption would be delayed for that reason. The exchange of gas and fluid, however, is measured and known in each case and, when considered in connection with the size of the ventricular and subarachnoid spaces, as demonstrated by x-ray, permits this group to be ruled out of consideration. Forty-four such cases occurred in the series

of 208 patients who were followed. One case will serve to illustrate this group. A boy, 19 years of age, with a convulsive state of traumatic origin, was found to have a porencephalic cyst and cerebral atrophy. Because of an asymmetrical subarachnoid filling cortical adhesions had been suspected also. The absorption of gas in this case was apparently slightly delayed, but, because 275 c.c. had been injected, it was felt that the slow disappearance of the gas did not actually represent an abnormally slow rate of absorption of cerebrospinal fluid. (For further discussion, see under Results.) Other patients in whom small and inadequate encephalographic injections were obtained were not included in this series.

As a rough criterion for the normal encephalographic injections of ethylene, the average values found in 100 cases previously reported (2) may be mentioned:

Children up to six years.....	80 c.c.
Children from six to sixteen.....	100 c.c.
Adults (sixteen years and over).....	136 c.c.
Large adults (maximum normal).....	150 c.c.

3. Because of the viscosity and surface tension of fluids, a gas, following its encephalographic injection, tends to displace with difficulty the cerebrospinal fluid in the more narrow and tortuous channels of the supracortical subarachnoid spaces. This would be particularly true if these channels were abnormally constricted or partially blocked, as, for example, by cortical adhesions. Under such conditions the gas would be limited, for the most part, to the larger channels—the basal cisterns and ventricles. Because of this fact and also because the surface contact between fluid and gas would be more limited, the absorption of the gas would be retarded. Under ordinary conditions there is a fair margin of safety in the absorptive mechanism—in the extent of the absorptive bed and the size of the subarachnoid channels leading to it. Under the abnormal conditions considered, however, the margin of safety would be reduced and, correspondingly, the absorption of gas following encephalography would be retarded for the reasons already

mentioned. Evidence will be presented to show that the retardation in the absorption of ethylene occurring under such conditions is appreciable and, in case of a progressive lesion, definitely antedates any true delay in the absorption of the cerebrospinal fluid. Beyond the critical point which marks the limit of the normal margin of safety in the absorptive mechanism, increased cerebrospinal fluid pressure, hydrocephalus, and further retardation in the absorption of gas occur. It may be concluded that, in the presence of small and poorly filled subarachnoid spaces, with ventricles of normal size (aside from any distortion or shift) and normal cerebrospinal fluid pressure, a slightly delayed rate in the absorption of the gas suggests an early lesion tending to obliterate a portion of subarachnoid spaces or absorptive bed, but which is not sufficiently advanced to render the total absorptive mechanism inadequate for the absorption of all the cerebrospinal fluid formed. Also, if the encephalographic picture were essentially the same, *i.e.*, ventricles of normal size and small or poorly filled subarachnoid spaces, and yet the rate of absorption of the

gas was normal, the poor subarachnoid filling would be best explained on the basis of a chance, inadequate filling, and should not be interpreted as abnormal.

4. The fourth factor—pressure—is a minor and almost negligible one in affecting the rate of absorption of the gas, since the cerebrospinal fluid pressure was essentially normal in all the patients submitted to encephalography and the variations of the cerebrospinal fluid pressure subsequent to encephalography are roughly comparable. In cases of suspected brain tumor encephalography has been performed only when evidence of increased intracranial pressure was slight or absent and preliminary lumbar puncture in the horizontal position showed that the cerebrospinal fluid pressure was not raised appreciably over 200 mm. of water. Since the variations of body temperature are relatively slight in these cases, this factor may safely be disregarded.

Thus, with the qualifications considered above in mind, it seems that, in properly selected cases, it should be possible to interpret a delay in the rate of the disappearance of ethylene, injected encephalo-

TABLE I

Clinical Diagnosis	No. of Cases	Size of Ventricles		Size of Subarachnoid Spaces				Estimated Rate of Absorption	
		Normal	Dilated	Normal	Dilated	Little or no gas	Asymmetrical	Normal	Delayed
Meningo-encephalitis	10	4	6	1	2	6	1	2	8
Brain tumor suspects	26	19	7	4	6	7	9	16	10
Convulsive state (idiopathic)	56	48	8	39	4	9	4	52	4
Convulsive state (post-traumatic)	23	18	5	8	5	6	4	20	3
Post-traumatic head syndrome	6	6	0	2	2	1	1	5	1
Cerebro-vascular disease	8	5	3	1	6	0	1	8	0
Maldevelopment of C.N.S.* (Congenital, infectious, post-traumatic)	22	11	11	6	8	6	2	18	4
Psychoneurosis	2	2	0	2	0	0	0	2	0
Miscellaneous	11	8	3	6	1	3	1	7	4
Total	164							130	34

* Central nervous system.

graphically, in terms of pathological processes concerned either with the formation or the absorption of cerebrospinal fluid.

Results.—In 208 cases in which a careful follow-up was made,¹ 44 patients had exchanges in excess of the normal limits established. (See Interpretation 2.) The high incidence of these cases probably reflects only the fact that the procedure is reserved for patients in whom cerebral atrophy is frequently present. However, it is interesting to note that, in spite of the relatively large injections of gas in these cases, only eight patients showed an apparent slight delay in the rate of absorp-

tion of ethylene. This probably reflects the large margin of safety existing normally in the absorptive mechanism, but may also indicate that our criteria for the limits of normal injection may be somewhat too conservative. The remaining 164 cases were considered suitable material for the proposed study.

The clinical types represented in these 164 patients are shown in Table I, together with the roentgenographic interpretation of the size of the ventricular and subarachnoid spaces and the estimated rate of absorption of cerebrospinal fluid.

Thirty-four patients showed an ab-

TABLE II—NON-TUMOR PATIENTS WITH ESTIMATED DELAYED RATE OF ABSORPTION—SLOW C.S.F. FORMATION?*

Case	Age	Sex	Clinical Diagnosis	Encephalographic Data						Estimated Rate of Absorption
				Initial pressure (mm. H ₂ O)*	Volume (c.c.) of Gas Injected	Size of Ventricles	Filling of Subarachnoid Spaces	Size of Basal Cisterns	Diagnosis	
C. S.	13	F	Disseminated myelencephalitis	400	100	Large normal	Normal (?) slight cortical atrophy	Slightly dilated	Normal	Slightly delayed
J. A.	22	M	Convulsive state (post-traumatic)	600	130	Large normal R > L	Small channels diffusely scattered over cortex	Dilated	Atrophy of rt. cerebrum	Moderately delayed
R. Ja.	1	M	Mongolian idiot	270	60	Large normal	Dilated	Large	Cortical aplasia	Slightly delayed
G. T.	27	M	Convulsive state (rt. Jacksonian)	500	125	Normal	Normal	Normal	Normal	Moderately delayed
Z. B.	24	M	Rt. hemiparesis and hemihypesthesia; etiology(?)	490	110	Normal	Normal	Normal	Normal	Moderately delayed
D. M.	2	M	Convulsive state (idiopathic)	310	65	Slightly dilated (?)	Normal	Normal	Normal	Markedly delayed
R. Ju.	7 mos.	M	Convulsive state (maldevelopment - C.N.S.)	220	70	Dilated	Dilated, especially in frontal and occipital areas	Dilated	Cerebral agenesis	Markedly delayed

* Initial C.S.F. pressure taken in sitting position and under anesthesia.

¹ Other patients, lacking adequate follow-up data or in whom an unsatisfactory filling occurred, were not included.

normal delay in the disappearance of the ethylene gas. These patients may be con-

veniently subdivided into two groups on the basis of the encephalographic findings: (1) those who presented normal or dilated subarachnoid spaces and (2) those who

absorption of gas occurred in the presence of normal or slightly dilated subarachnoid spaces. The details of these cases are presented in Table II. Since the gas

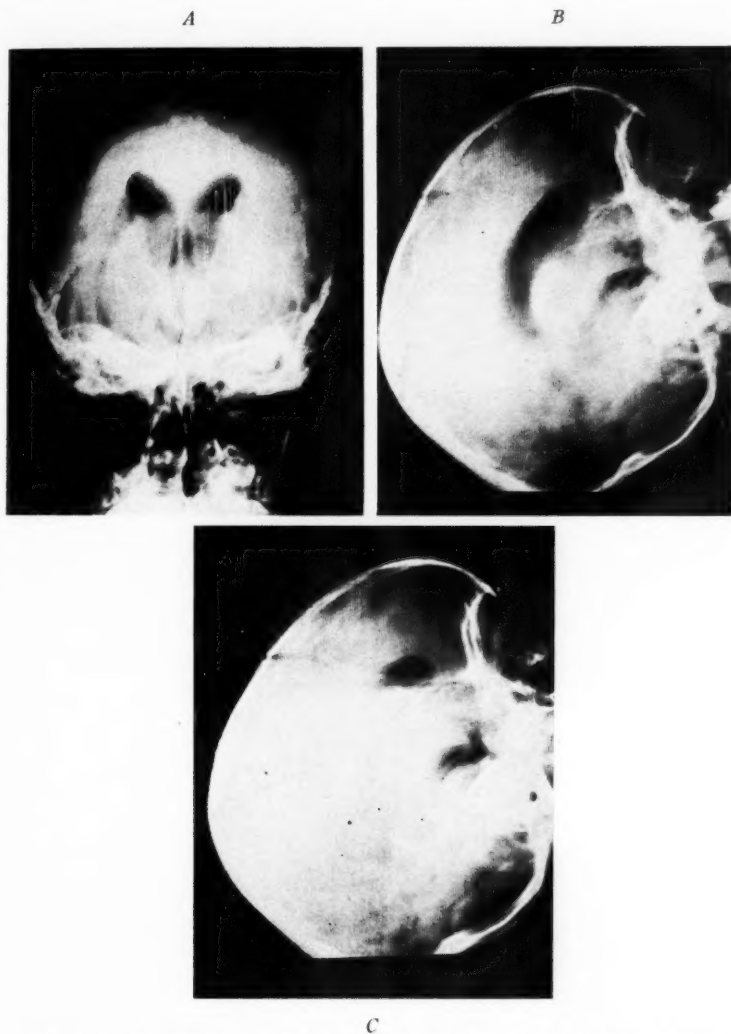


Fig. 2. L. C., female, 5 years of age. Clinical diagnosis: Right hemiplegia, etiology (?); two-year duration, 80 c.c. volume exchange of C.S.F. and ethylene gas. Roentgenographic diagnosis: Hydrocephalus. Follow-up views were taken at 5, 7, and 24 hours, and show a slightly delayed rate of absorption of the ethylene gas. For further details, see Table III. Note the absence of subarachnoid filling. (A) Anteroposterior projection. (B) Horizontal transverse projection, initial view. (C) Horizontal transverse projection, 24-hour view; 90 per cent estimated absorption.

failed to show a proper filling of the supracortical subarachnoid spaces.

Group I.—In seven instances a delayed

reached the supracortical spaces through normal or dilated subarachnoid channels, a delay in the rate of the disappearance of

the gas on the basis previously suggested (see Interpretation) cannot be accepted in these cases. Pathologic changes of the arachnoid villæ, as described by Fay and Winkelman (4) in a group of cases of cortical

the most likely explanation in this group. (See Interpretation 1.) The exact nature of such a condition—atrophy of the choroid plexus or a physiological dysfunction—can only be conjectured.

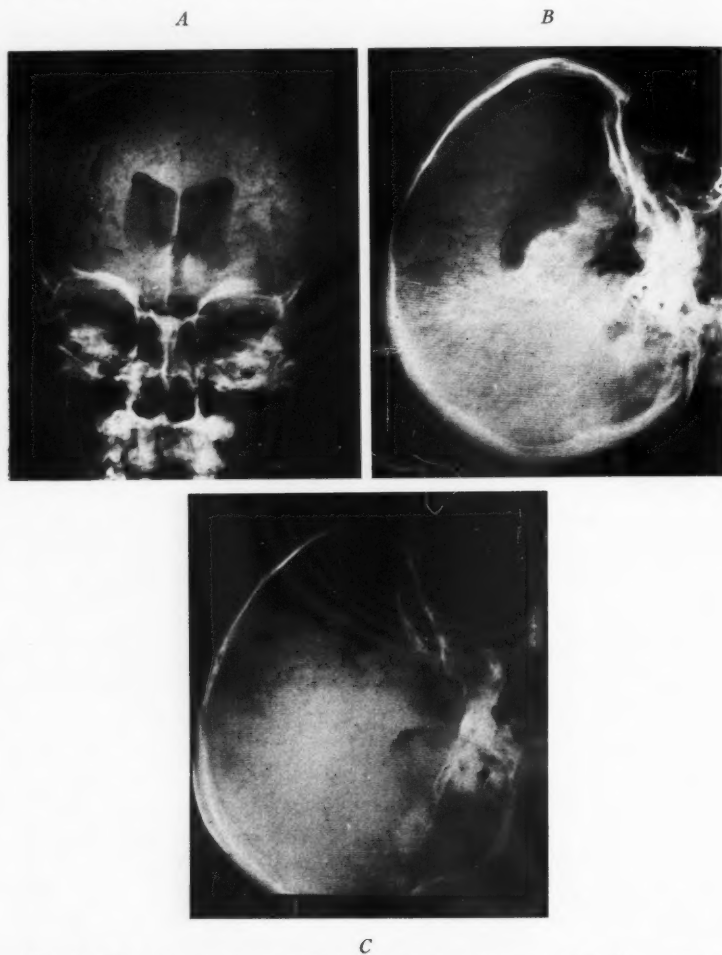


Fig. 3. S. A., 4 years of age. Clinical diagnosis: Congenital defective; 70 c.c. volume exchange of C.S.F. and ethylene gas. Normal encephalogram. (A) Anteroposterior projection. (B) Horizontal transverse projection, initial view. (C) Horizontal transverse projection, three-hour view; 90 per cent estimated absorption.

atrophy, likewise would not appear to explain this delayed absorption of gas, since such a block in the absorptive bed would scarcely be compatible with the normal, or even low, cerebrospinal fluid pressures observed in these cases. A sluggish flow of cerebrospinal fluid secondary to its subnormal formation would seem

Group II.—In the remaining 27 cases the delayed absorption of gas was associated with a markedly limited filling, either general or asymmetrical, of the supracortical subarachnoid spaces. Ten of these 27 patients were tumor suspects in whom the obliteration of the subarachnoid spaces and blocking of the absorptive

bed presumably were caused by a space-consuming lesion. The other 17 cases may conveniently be considered separately.

Non-tumor Group with Delayed Absorption.—The work of Key and Retzius (8), confirmed by Weed (14) and Naffziger (11), again more recently by the studies of Iwanow and Romodanowsky (7) and Spiegel and Sommer (13), demonstrated that the main bed for the absorption of cerebrospinal fluid is situated in the subarachnoid spaces overlying the cerebral hemispheres. In cases of delayed absorption, therefore, direct involvement of this absorptive bed or of the channels leading to it, is to be suspected. The presence of arachnoid adhesions secondary to a meningo-encephalitic process, either infectious or traumatic in origin, is a possibility which must be considered in such cases. The encephalographic picture in this group is characteristic. Failure of proper filling or an asymmetrical filling in the supracortical subarachnoid spaces with or without dilated ventricles and basal cisterns has constituted the picture associated with the delayed absorption (Fig. 2). The poor subarachnoid filling is often passed over and the dilated ventricles, when present, have been considered within the upper limits of normal, or possibly a cerebral atrophy or early hydrocephalus. Compare these pictures with the normal as illustrated in Figure 3.

Of the 17 patients showing this condition, that is, a poor supracortical subarachnoid filling associated with a delayed absorption of the gas, two (namely, M. P. and A. K.) were borderline cases and have been included only because the suggested delayed rate of absorption seemed the best explanation of both their clinical and encephalographic findings. A meningo-encephalitic process of infectious or traumatic origin was compatible with the clinical findings in all these cases and was definitely suggested in 12 of them. The pertinent data in connection with these cases are presented in Table III.

On the basis of ventricular enlargement

and an encephalographic injection of gas beyond the limits established for a proper interpretation of the rate of absorption of the gas in this procedure, it might be argued that two cases in this series, namely, E. K. and R. H. (see Table III), have been improperly included. In these instances, however, the delay in absorption was unusually marked and seemed out of proportion to the slight delay which might have been expected from the degree of ventricular dilation and the amount of gas injected. For this reason and because, in addition, they seem best explained clinically on the basis of a meningo-encephalitis, they have been included as examples of the more advanced stages of the condition under consideration. In the presence of the normal cerebrospinal fluid, and normal cerebrospinal fluid pressure found in these patients, their encephalographic findings must be accounted for by an old meningo-encephalitic process of sufficient severity to have left the structural changes observed and yet not of sufficient severity to have produced a permanent functional decompensation in their absorptive mechanisms.

In one of these cases operation afforded opportunity for a correlation of the pathologic changes with the encephalographic findings and delayed rate of absorption.

Protocol.—K. T., 21 years, of age, male.

History.—Six years ago this patient was hit on the head by a baseball. He suffered an acute septic condition of scalp three weeks later. Subsequently a right frontal abscess was diagnosed. An abscess in the right frontal region was drained six weeks later. This frontal abscess had been aspirated three times in the past six years—the last time one year before entry “without success.” This patient’s complaints were headaches at time of aspiration, slight subjective hemipareses after a series of aspirations, and generalized, non-focal convulsions for the last three and a half years.

Examination.—The positive contributive

findings were limited to scars and hyperesthesia on the forehead and the right fronto-parietal region, a positive Hoffman's sign on the left, and slightly increased biceps and Achilles reflexes on the left side.

Encephalogram.—This showed "large normal" ventricles with the anterior horns slightly shifted to the right. The sub-arachnoid spaces were normal on the left, but did not show in the right frontal and parietal regions, especially in the neighborhood of the old burr hole. Of the 150 c.c. of ethylene injected, 80 per cent

had disappeared in four and a half hours, and 85 per cent in seven and a quarter hours. The rate of disappearance of the ethylene gas was estimated to be slightly delayed in comparison with the "normal curve" (Fig. 1).

Diagnosis.—Cerebral scar and cortical adhesions—right frontal.

Operation.—Revealed a cortical scar in the right frontal lobe. A right frontal lobectomy was performed.

Pathological Study.—Showed a moderately adherent arachnoid which, on micro-

TABLE III.—NON-TUMOR PATIENTS WITH ESTIMATED DELAYED RATE OF ABSORPTION—
ABSORPTIVE BLOCK

Encephalographic Data										
Case	Age	Sex	Clinical Diagnosis	Initial C.S.F. Pres- sure (mm. H ₂ O)*	Volume (c.c.) of Gas Injected	Size of Ventricles	Filling of Subarachnoid Spaces	Size of Basal Cisterns	Diagnosis	Estimated Rate of Absorption
M. P.	14	F	Lawrence- Moon - Bie- dle Syn- drome	565	97	Slightly dilated	Only a few "streaks" in frontal areas	Dilated	Absorptive block (?)	Slight de- lay (?)
A. K.	25	M	Cephalagia since influ- enza 2 years before	620	104	L. (?) slightly dilated	Slight asym- metry R > L	Normal	Left cortical adhesions. Right cortical adhesions (?)	Slight de- lay (?)
C. C.	28	M	Convulsive state; etiol- ogy (?)	510	145	Slightly dilated	Very little gas	Dilated	Early hy- droceph- alus (?)	Slightly delayed
K. T.	21	M	Convulsive state after brain abscess —rt. frontal	545	150	Large normal	Little or no gas in rt. fronto- parietal area	Normal	Rt. frontal adhesions	Slightly delayed
L. C.	5	F	Rt. hemiple- gia; etiology (?)	—	80	Slightly dilated	Very little gas	Dilated	H y d r o - cephalus	Slightly delayed
E. A.	1½	F	Microcephaly —mental re- tardation	220	60	Greatly dilated	No gas	No gas	Cortical adhesions (?)	Slightly delayed
A. P.	25	M	Convulsive state; etiol- ogy (?)	520	125	Large normal	Only slight "streak- ing" in frontal areas	Normal	Normal	Slightly delayed
R. M.	16	M	Convulsive state since meningo- encephalitis	645	120	Dilated with cyst	Little or no gas	Dilated	P o r e n - cephalic cyst	Slightly delayed

scopic examination, was found to be greatly thickened.

The partial block in the absorptive bed in this case, as shown in the encephalograms and verified pathologically, seems to agree with the findings of only mildly dilated ventricles and a delayed absorptive rate of slight degree.

As a corollary to this group which showed a delayed absorption of gas, it is interesting to consider those patients who were diagnosed as having a meningo-encephalitic process, but who did not show a delayed rate of absorption. The essential facts in these cases are presented in Table IV.

One patient, O. K., a boy 17 years of age, with undeniable clinical and laboratory evidence of a low grade encephalitis (corroborated by a burr hole exploration), presented no ventricular or subarachnoid abnormality upon encephalography and furthermore had a normal rate of absorption of the ethylene gas. This patient was followed through to eventual complete clinical recovery.

In the second patient, J. H., an arachnoiditis in the left temporal region over an area 4×6 cm. in size was demonstrated at operation. Likewise, in patient B. K.,

A. G.	8	M	Lt. hemiparesis and Jacksonian epilepsy since "meningitis"	640	110	Normal	No gas except in area of Isle of Reil on rt.	Dilated	Agenesis of cortical adhesions (?)	Slightly delayed
M. M.	23	M	Hemiparesis and Jacksonian epilepsy since meningo-encephalitis	630	136	Dilated	Slight "streaking" only	Dilated (?)	Cortical adhesions (?)	Slightly delayed
J. F.	17	M	Convulsive state since depressed frontal fracture	600	120	Rt. dilated; L. normal	Chiefly frontal "streaking" R > L	Dilated	Cortical scar adhesions	Slightly delayed
J. O.	10	F	Lt. hemiparesis and convulsive state since "meningitis"	400	70	Dilated R > L	Only few "streaks" in left frontal region	Dilated	Cortical adhesions	Slightly delayed
D. T.	10	F	Spastic paraplegia—birth trauma	500	75	Dilated	Only slight frontal "streaking"	Dilated	Cortical adhesions	Slightly delayed
E. K.	18	M	Convulsive state following meningo-encephalitis	470	160	Dilated	Only slight frontal "streaking"	Dilated	Hydrocephalus	Markedly delayed
R. H.	11	M	Convulsive state. Mental retardation. Encephalitis (?)	500	120	Dilated	Very little gas	Dilated	Hydrocephalus	Markedly delayed
R. S.	33	M	Jacksonian epilepsy, post-traumatic	220 (prone)	135	Dilated	Only slight frontal "streaking"	Dilated	Hydrocephalus	Markedly delayed
J. B.	7	M	Mental retardation, post-traumatic head syndrome	540	60	Normal	No gas	Dilated	Normal	very markedly delayed

* Initial C.S.F. pressure taken with patient in sitting position and under anesthesia.

limited areas of adhesions were found about the left frontal lobe near the site of the cortical scar, which had been demonstrated by the encephalograms and which was excised by lobectomy. The normal rate of absorption in these cases seems entirely compatible with such a sharply delimited involvement of the meninges.

The fourth patient, L. G., gave clinical evidence of a post-encephalitic condition. The convulsive state and mental retardation dated from a period of infections of

ears and sinus at the age of one and a half years. However, the usual sequelæ of encephalitis—cerebral atrophy or cortical adhesions—were not demonstrable by encephalography and the rate of absorption tended to corroborate the essentially normal findings in this case.

In the fifth patient, D. H., the encephalographic findings in some respects suggested a cortical scar, but the lack of any history or clinical findings which would tend to corroborate this diagnosis, as well as the

TABLE IV.—NON-TUMOR PATIENTS WITH ESTIMATED NORMAL RATE OF ABSORPTION—MENINGO-ENCEPHALITIS AND SUSPECTED CORTICAL ADHESIONS

Case	Age	Sex	Clinical Diagnosis	Encephalographic Data					Estimated Rate of Absorption
				Initial C.S.F. Pressure (mm. H ₂ O)*	Volume (c.c.) of Gas Injected	Size of Ventricles	Filling of Subarachnoid Spaces	Size of Basal Cisterns	
O. K.	17	M	Chronic leptomeningitis	335 (prone)	170	Normal	Normal	Normal	Normal
J. H.	39	M	Chronic arachnoiditis	540	11	Normal	Little gas	Normal	Normal
B. K.	8	F	Lt. frontal cortical scar and adhesions	270	70	Lt. dilated; Rt. normal	Poor filling	Normal	Lt. frontal cortical scar
L. G.	10	F	Jacksonian epilepsy mental retardation post-encephalitic (?)	390	72	Normal	Normal	Normal	Normal
D. H.	18	M	Convulsive state; idiopathic	340	95	Dilated	Normal	Normal	Cortical scar (?)
W. P.	27	M	Convulsive state; idiopathic	260	70	Normal	Very little gas	Normal	Adhesions
M. S.	1 1/2	M	Convulsive state; post-traumatic	550	60	Normal	R > L	Dilated	Adhesions Lt. cortex
M. E.	8	F	Convulsive state; post-traumatic (?)	440	75	Normal	R < L	Normal	Adhesions Rt. cortex
W. C.	1	M	Lt. hemiplegia—birth injury	265	55	Normal	R < L	Normal	Cortical adhesions on rt. (?)
D. B.	19	M	Jacksonian epilepsy etiology (?)	460	135	Normal	Poor filling	Normal	Cortical adhesions (?)
B. J.	4	F	Mental retardation; agenesis	530	90	Normal R > L	Slight asymmetry R < L	Dilated	Cortical adhesions (?)

* Initial C.S.F. pressure taken with patient in sitting position and under anesthesia.

symmetrical subarachnoid filling and normal rate of absorption of the gas in the encephalogram, made this diagnosis unlikely.

In six other patients cortical adhesions had been suspected on the basis of asymmetrical or poor subarachnoid filling over the cortex. The ventricles were not abnormal, however, and the rate of absorption was definitely within normal limits. Although an adhesive process of circumscribed character might well be compatible with a normal rate of absorption, as dem-

onstrated in patients J. H. and B. K., an asymmetrical subarachnoid filling involving the spaces over one entire cerebrum, such as was present in four patients, and the lack of filling over both cerebral hemispheres, as seen in the other two, can scarcely be explained on such a basis. The accuracy of the method is sufficient to detect such gross blocks in the absorptive bed, and probably is adequate to show a delayed rate of absorption when approximately one-fifth of the absorptive bed is involved, as previously illustrated in the case of

TABLE V-A.—TUMOR SUSPECT PATIENTS WITH ESTIMATED DELAYED RATE OF ABSORPTION

Case	Age	Sex	Clinical Diagnosis	Encephalographic Data						Estimated Rate of Absorption
				Initial Pressure (mm. H ₂ O)*	Volume (c.c.) of Gas Injected	Size of Ventricles	Filling of Subarachnoid Spaces	Size of Basal Cisterns	Diagnosis	
M. M.	35	F	Lt. temporo-parietal glioma (verified)	625	90	Normal R > L	No gas	Normal	Tumor	Markedly delayed
J. F.	35	M	Rt. temporal glioma (verified)	540	135	Normal	R < L Marked asymmetry	Normal	Tumor	Moderately delayed
M. R.	44	M	Lt. temporal tumor (died—no autopsy)	540	130	Normal	Little or no gas	Normal	Tumor	Moderately delayed
G. W.	37	F	Rt. frontal meningeoma (verified)	420	100	Normal R < L	R < L Chiefly left frontal	Normal	Tumor	Moderately delayed
A. J.	17	M	Osteoma of skull	575	85	Normal	Only slight in frontal areas	Normal	Tumor	Slightly delayed
A. A.	30	M	Lt. temporal hemangioma (verified)	550	132	Slightly dilated	Few "streaks" in frontal areas	Slightly dilated	Tumor	Slightly delayed
R. H.	28	F	Rt. frontal astrocytoma (verified)	920+	90	Rt. dilated; Lt. no gas	No gas	Normal	Tumor	Markedly delayed
W. C.	33	M	Brain tumor(?)	750	125	Dilated	No gas	No gas	Tumor (?)	Slightly delayed
F. T.	26	F	Lt. frontal cholesteatoma (verified)	620	92	Rt. dilated R > L	Little or no gas	Normal	Tumor	Slightly delayed
E. E.	32	M	Rt. temporo-parietal tumor	600	130	Normal (?)	Lt. normal; Rt. no gas	Normal	Tumor (?)	Moderately delayed

proved cortical adhesion in the right frontoparietal region.

The failure of subarachnoid filling, as seen in the patients W. P. and D. B., is not uncommon and, alone, can scarcely justify

difficult encephalographic injection of ethylene, in the case of W. P., contributed to the impression of arachnoidal adhesions about the spinal cord. Clinically, both patients presented convulsive states of unknown

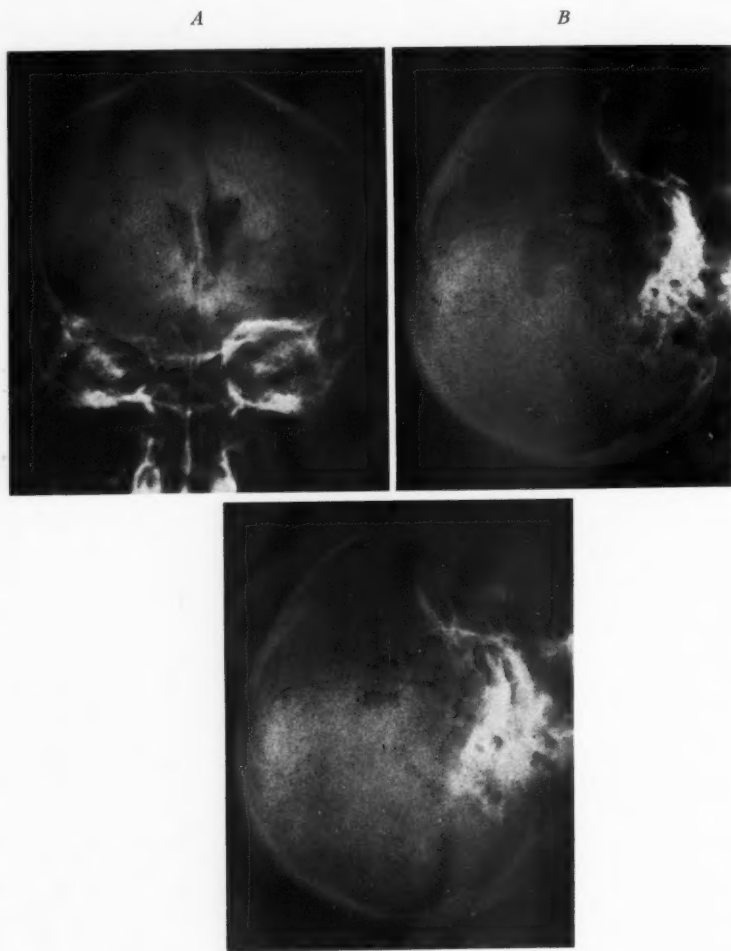


Fig. 4. G. W., female, 37 years of age. Clinical diagnosis: Right frontal brain tumor; 20 months' duration of symptoms, 100 c.c. volume exchange of C.S.F. and ethylene. The rate of absorption of the ethylene was estimated to be slightly delayed. For further details, see Table V-A. Note the absence of subarachnoid gas on the side of the tumor, which is indicated by the shift of the falx cerebri and the lateral ventricles, the posterior displacement and distortion of the right anterior horn, and by the erosion of the right superior bony orbit. Roentgenographic diagnosis: Right frontal tumor. (A) Anteroposterior projection. (B) Horizontal transverse projection, initial view. (C) Horizontal transverse projection, six-hour view; 80 per cent estimated absorption.

the diagnosis of cortical adhesions. A slow drainage of cerebrospinal fluid and

etiology with little in their histories, physical findings, or examinations of the cere-

brospinal fluid to suggest a meningo-encephalitis.

Anatomical variations or possibly deflecting (not obstructive) adhesions about the base would seem to be a more likely explanation in the four cases of asymmetrical filling of the subarachnoid spaces.

The value of this functional check on the usual x-ray interpretation is thus of service not only in corroborating the diagnosis of cortical pathology, presumably of post-traumatic or meningo-encephalitic origin, but also in differentiating from this group certain other cases which would have been so classified by the usual methods.

Brain Tumor Patients with Delayed Absorption.—Of 26 patients suspected of brain tumor (see Table I), in whom the cerebrospinal fluid pressure was sufficiently low to permit the use of encephalography, the diagnosis of brain tumor was made in 16 cases, either by the encephalograms or by pathological examination, while the possibility of tumor was ruled out by the encephalographic findings in nine of the remaining ten patients. Ten of those diagnosed as having brain tumors showed abnormally slow rates of absorption of ethylene,

and the other six were estimated to have normal rates of absorption. The pertinent data on these 16 cases of tumor are presented in Table V-A. Although such an analysis of these cases does not permit clear-cut explanation of a delayed rate of absorption in ten of the patients, as opposed to a normal rate in the other six in whom the diagnosis of tumor was made, the patients with delayed absorption had, for the most part less gas in the subarachnoid spaces, and in this respect tended to simulate the usual appearance of a ventriculogram (Fig. 4).

Also worthy of note in this connection is the fact that dilated ventricles occurred much more frequently in the group showing a delayed absorption rate. In fact, in the group showing a normal rate of absorption ventricular dilatation was found in one instance only, and the diagnosis in this case was that of an intraventricular tumor (Table V-B).

That these differences are significant is suggested by the findings in the patient M. R. In the initial encephalogram the right ventricle appeared a trifle larger than the left, which seemed slightly compressed and distorted. There was a ques-

TABLE V-B.—TUMOR SUSPECT PATIENTS WITH ESTIMATED NORMAL RATE OF ABSORPTION

G. M.	56	F	Rt. parietal meningeoma (verified)	400	110	Normal R < L	Slight asymmetry R < L	Normal	Tumor	Normal
J. L.	26	F	Intraventricular tumor	630	130	Rt. dilated; Lt. normal	Slight asymmetry R < L	Normal	Tumor	Normal
R. S.	43	M	Rt. temporo-parietal tumor	—	135	Normal R < L	Slight asymmetry R < L	Dilated	Tumor	Normal
C. D.	40	M	Rt. fronto-parietal astrocytoma (verified)	500	100	Normal	Slight asymmetry R < L	Normal	Normal	Normal
J. S.	48	M	Adenocarcinoma of choroid plexus (verified)	650	100	Normal R < L	Rt. atrophy frontal; Lt. normal	Normal	Tumor	Normal
E. S.	27	F	Craniopharyngeoma	500	145	Normal	Normal	Dilated	Tumor	Normal

* Initial C.S.F. pressure taken in sitting position and under anesthesia (Avertin).

tionable shift of the ventricular system to the right. Little or no gas could be discerned in the supracortical subarachnoid spaces. A ventriculogram was performed on the patient four months later and showed a striking change. The right ventricle was considerably dilated. The anterior horn of the left ventricle was also dilated, while the body was compressed. The anterior portion of the third ventricle was dilated, while the posterior portion appeared obliterated. There was a marked shift of the ventricular system to the right. No gas was visualized in the subarachnoid spaces. The marked increase in the dilatation of the ventricle with the advancement of the condition strikingly illustrates the process in its progression from the early to the terminal stages. The tendency for dilated ventricles to occur with obliterated subarachnoid spaces and for this combination to be associated with a retarded rate of absorption thus simulates the picture found in meningo-encephalitic conditions as previously discussed. The clinical course, however, as well as the shift and distortion of the ventricular system, clearly differentiates the cases of brain tumor.

In this connection it is interesting to conjecture on the abnormal cerebrospinal fluid dynamics accompanying brain tumors. The explanation of an increased intracranial pressure in the presence of ample and incompletely collapsed ventricles has not been clear on a simple, space-consuming basis. Obliteration of space in the smaller and more susceptible subarachnoid spaces over the cerebral cortices, or similar blockage of the cerebrospinal fluid pathways at the narrow subarachnoidal channel of the incisura might well produce a progressively increasing pressure commensurate with the degree of absorptive block. The actual obliteration of the subarachnoid spaces, evidenced by encephalography and checked by operative observation, in combination with dilatation of these ventricular spaces (not necessarily distorted or compressed), and the finding of delayed rates of absorption in the more advanced stages, strongly support

this explanation. The progression of changes as illustrated in the case of M. R. contributes to the same interpretation.

Discussion.—It is an interesting fact that, in the group of patients with brain tumor (Table V), ventricular dilatation was found to a slight degree in only four of the ten cases showing a delayed rate of absorption, whereas in the corresponding group of patients who did not have tumor (Table III) definitely normal ventricles were found in only two of the 17 patients showing the delayed rate of absorption. Furthermore, the degree of ventricular dilatation in this latter group tended to be far more advanced than in the case of the tumor group. The explanation of these facts must be sought in a proper interpretation of the absorption of gas following encephalography with ethylene, keeping in mind the clinical conditions associated with the delayed absorption.

As suggested (see under Interpretation 3), a delayed rate of disappearance of the gas may merely reflect an early obliteration of the subarachnoid channels and does not necessarily indicate a true retarded absorption of cerebrospinal fluid. In this early stage the retarded disappearance of the gas is consistent with ventricles of normal size, and normal cerebrospinal fluid pressure. The two patients without tumor, with ventricles of normal size, and the majority of patients with tumor, would seem to fit into this category. If the process is progressive, as in the case of a tumor or chronic, low-grade leptomeningitis, this early change foreshadows the alterations to come with progressive blocking of the absorptive bed, namely, dilatations of the ventricles and basal cisterns in the presence of increased cerebrospinal fluid pressure.

If such a process should regress at any stage, as might occur in the case of an acute encephalomeningitis, residual structural changes might be found associated with a delayed rate of absorption of gas. The structural changes would consist of more or less obliterated, supracortical, subarachnoid spaces, with or without dilated ventricles and basal cisterns—depending upon

the duration and severity of the acute process. Provided the residual absorptive mechanism was still adequate for the absorption of all cerebrospinal fluid formed, the cerebrospinal fluid pressure would be normal. Such an explanation would seem most likely in the patients without tumor, who showed dilated ventricles and basal cisterns.

Previous studies on the rate of absorption of cerebrospinal fluid have utilized the method of determination of urinary excretion of agents following their injection into the ventricular or subarachnoid spaces. Thus Dandy (3) used the dye phenolsulphonaphthalein, and Foerster (5) used sodium iodide. Other workers, using the same methods or modifications of them, have reported rather striking delays in the appearance of the dye or iodide in the urine and prolonged duration of excretion in such conditions as schizoid stages, especially of the catatonic type (6), (15), cerebral syphilis (6, 12, 15) postencephalitic disorders, (9), and other organic diseases of the central nervous system (10), especially those involving the meninges. In individual cases, however, the tests have proved of little value. The obvious defect in these procedures has been that set amounts of the dye or iodide have been injected in all cases regardless of the volume of cerebrospinal fluid with which the dye or iodide was being diluted. As pointed out above (see under Interpretation 2), estimation of the rates of absorption cannot be made in individual cases without such knowledge. The follow-up observations on the rate of disappearance of ethylene, on the other hand, have the advantage that the sizes of the ventricles and subarachnoid spaces are shown by the encephalograms and the volume of the exchange of gas and fluid is determined at the time of injection. The estimation of the rate of absorption, because it is performed in conjunction with encephalography, is provided with the data which are essential for proper interpretation in the individual case.

As has already been brought out, delay in the absorption of ethylene following en-

cephalography does not necessarily indicate a delayed absorption of cerebrospinal fluid. Such a delay in the absorption of gas, however, does indicate either an abnormally slow formation of cerebrospinal fluid or a limited margin of safety in the absorptive mechanism. In the latter instance, when the process is progressive, the delayed absorption of gas foreshadows the changes to come when the margin of safety is overstepped, namely a delayed absorption of cerebrospinal fluid, an increased cerebrospinal fluid pressure, and hydrocephalus. The dyes and iodides, in that they are given in the form of solutions, would presumably correspond more closely with the cerebrospinal fluid in their absorptive characteristics. In early cases, in which obstruction was only partial, a delay in absorption, as occurs with the gas, could not be expected with such solutions, since actually absorption is occurring within normal limits. The absorption of gas, thus, serves as a delicate and early diagnostic test and, in this respect again, has a distinct advantage over the dye and iodide solutions.

In the interpretation of this procedure it must be remembered that it is an estimate, with rather wide variables involved, and, like all laboratory tests, is completely dependent for what accuracy it may possess upon the carefulness of its execution. As a single test, which ordinarily cannot be repeated on the same patient, it must be interpreted with caution, keeping in mind the condition of the patient at the time and the pitfalls of comparing one case with another. Consequently, it is not a test which will give indisputable evidence by itself. With proper caution in interpretation, however, it can be of great value, as has been pointed out, in corroborating, and giving additional information to, the encephalographic diagnosis. In the presence of suggestive findings, such as rather large ventricles and small cortical subarachnoid spaces, it may be advantageously correlated with the clinical findings to establish the diagnosis. In the presence of an apparent delayed rate of absorption, the ven-

tricles and subarachnoid spaces should be carefully re-examined for possible abnormality.

CONCLUSIONS

1. The rate of disappearance of ethylene gas following its encephalographic injection may be estimated by means of follow-up roentgenograms, and, in properly selected cases, may be correlated with the presence or absence of pathological processes involving the supracortical subarachnoid spaces and the mechanism concerned with the formation and absorption of cerebrospinal fluid.

2. In a few instances a delayed rate of absorption occurred in the presence of normal or dilated subarachnoid spaces. The possibility of faulty formation of cerebrospinal fluid is suggested in this group.

3. The majority of patients showing a delayed absorption have presented the characteristic findings of little or no gas in the subarachnoid spaces or an asymmetry of the subarachnoid filling. This condition has been observed in cases of brain tumor and in extensive supracortical arachnoidal adhesions of infectious or traumatic origin. Dilatations of the ventricles and basal cisterns occurred in the majority of cases of the latter type. An interpretation of the findings in these cases, as well as in others, is presented.

4. The use of this procedure is of distinct diagnostic value in corroborating and clarifying the usual static interpretation of encephalograms.

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fessor of Surgery; Robert S. Stone, M.D., Associate Professor of Roentgenology; Charles Capp, M.D., Assistant Professor of Roentgenology; O. W. Jones, Jr., M.D., Associate Professor of Surgery.

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THE SITUATION OF RADIOLOGY IN MEDICAL EDUCATION IN THE UNITED STATES AND CANADA¹

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RECENT medical literature frequently refers to the "advances of the last twenty-five or fifty years." Such periods of time cannot properly be applied to the progress of radiology. Its advancement must of necessity be measured by some shorter standard. In this country radiology is scarcely forty years old. Yet, in that brief period, our specialty has made stupendous strides. Skinner (1) aptly states that "no other field of human research has enjoyed such immediate and universal participation, such profound adaptability to problems of human disease, such extensive availability to the world's population, and such splendid benefit to unconquered fields of diagnosis and therapy as roentgen diagnosis and radiation therapy."

Although medicine, generally, has been passing through a very difficult period, a period in which economic problems and the socialization of medicine have been uppermost in the minds of those controlling the destiny of organized medicine, radiology has continued to advance. In like manner, during this same time, the scope of medical education has expanded considerably. Hospitals have improved their physical equipment; a closer relationship has sprung up between hospitals and medical schools, and an increasing number of institutions, by fulfilling the "Principles of Graduate Medical Schools," have earned the right to give graduate medical instruction. It seems advisable, therefore, that an organization such as the International Congress of Radiology should set aside a certain time for the consideration of the tremendous problem of education in radiology. For concomitant with

the development of this specialty, the use of radiologic methods in medical education has been swift.

With these thoughts in mind, our President has asked me to prepare for you a statement concerning the present status of radiology in medical education in the United States. It is our hope that the consideration of some of the facts connected with this problem will assist in the further development of an even closer relationship between radiology and the other branches of medicine and surgery, particularly in reference to the newer conceptions and methods of medical education. In order to discuss this subject in as systematic and comprehensive a manner as possible, we should like to review some of the influencing factors that have placed radiology in its present position in medical education and then take up the details of its instruction in undergraduate, graduate, and even more advanced courses.

I. INFLUENCE OF THE AMERICAN MEDICAL ASSOCIATION UPON MEDICAL EDUCATION IN GENERAL

Medical education in the United States is regulated by rules and specifications of the American Medical Association, the Association of American Medical Colleges, and the various State requirements for licensure to practise (2). In 1900, statistics on the medical school situation were published by the American Medical Association, and in 1904, the Council on Medical Education was created. Since that time, the Council, through its annual conferences, inspections, and classification of medical schools, has formulated educational requirements which have promptly been embodied by the various States in their legal requirements for licensure to

¹ Presented at the Fifth International Congress of Radiology in Chicago, Sept. 13-17, 1937.

practise. These legal specifications, although they differ considerably in each State, have been important in forcing medical schools throughout the country to meet the accepted standards of education (2).

In the past, medical education has concerned itself almost exclusively with the training of physicians and contributions of discoveries regarding health and disease. The rapid growth in knowledge and the changes in social organization have greatly complicated the original problems of medical service (2). With the further production and perfection of various medical instruments and the advance of the physical sciences has come the development of specialism in medicine. In order to protect the public, the Council on Medical Education and Hospitals, of the American Medical Association, soon recognized that the resulting growth of specialism would have to be established upon a broad foundation of general medical training (3). In 1933, therefore, the House of Delegates authorized the Council to approve such special boards as should meet the specifications formulated by the Council. Working on this basis, the Council, in 1933-1934, organized an "Advisory Board for Medical Specialties," for the certification of medical specialists in the United States and Canada. In a comparatively short time, twelve certifying boards were created, and they have exerted a tremendous influence in improving both general and special medical education.

II. INFLUENCE OF RADIOLOGIC SOCIETIES UPON MEDICAL EDUCATION

The American Roentgen Ray Society held its first meeting in New York, December 13 and 14, 1900. Since that time, the organization has grown, both in wisdom and numbers, until at the present time, it has 432 active members, most of whom are Fellows of the American Medical Association. The Society has one meeting annually and maintains the "American Journal of Roentgenology and Radium Therapy" as its official organ.

This Journal also publishes the papers presented at the annual meeting of the American Radium Society, organized in 1916. This Society has 135 active members, most of whom are, also, Fellows of the American Medical Association.

The Radiological Society of North America was organized in 1920. Its official organ is RADIOLOGY. The active membership list of this Society numbers 1,237, with most of the members also Fellows of the American Medical Association. One meeting is held yearly.

The American College of Radiology was organized in 1923. It is concerned largely with medical education and economics; 260 members are listed in its directory.

In 1924, the American Medical Association established a Section on Radiology. This Section holds its meeting at the time of the annual session of the Association. Its members participate in the scientific exhibit, as well as in the other activities and deliberations of organized medicine.

In addition to these major radiologic societies, there are 36 local radiologic societies distributed in 29 of the States, with six Sections on Radiology as component parts of different State medical societies. Each one of these organizations is assisting in an admirable way to elevate the standard of radiology. The members are pledged to the study of radiology as it pertains to medicine, to provide for meetings, and to disseminate information through published articles.

III. INFLUENCE OF THE AMERICAN MEDICAL ASSOCIATION UPON RADIOLOGY THROUGH ITS COUNCIL ON MEDICAL EDUCATION AND HOSPITALS

Early in 1920, the specialty of radiology was invaded by lay practitioners and other unqualified individuals who set up "x-ray laboratories" to compete with the qualified radiologists. In order to overcome this and other evils, the American Medical Association was asked to provide for supervision and certification in the field of radiology. The House of Dele-

gates granted this assistance to radiology and assigned the task to the Council on Medical Education and Hospitals. The Council turned for help to the leading radiologists of the existing radiological societies. These radiologists formed an Advisory Committee and worked with the Council in setting down "Essentials for Admission to the List of Physicians Specializing in Radiology." "This committee was retained by the Council as a permanent one, and branch committees in every State were selected to pass upon the qualifications of those who applied for certification. The object was to provide the medical profession, hospitals, and the public with a list of men from which to make selection whenever the services of a radiologist were needed" (4). The regular, annual publication of this list since 1931 has proved itself a powerful educational force and a definite aid to radiology.

IV. REQUIREMENTS OF THE COUNCIL ON MEDICAL EDUCATION CONCERNING RADIOLOGIC SERVICES IN HOSPITALS

"In the approval of hospitals for internships and residencies, and in surveying all hospitals for registration, the requirements for radiologic services are definitely outlined. The earliest official set of hospital requirements by the Council on Medical Education and Hospitals was its 'Essentials in a Hospital Approved for Training Interns,' first issued in 1914. It has ever since that time been circulated among hospitals and has been used as a basis of approving them. The early issues of the 'Essentials' stated that the hospital should have: 'A roentgen-ray department in charge of an expert roentgenologist, and equipped to do roentgenographic fluoroscopic, and therapeutic work.'

"By 1925, this requirement was expanded to read as follows:

"The roentgen-ray department shall be in charge of a roentgenologist whose attainments are at least equal to those of other staff members and who shall supervise and instruct interns in all essential phases of roentgenology. The depart-

ment must be equipped to do roentgenographic, fluoroscopic, and therapeutic work. The intern should receive instruction both in regard to the technic and dangers of roentgen-ray application and also in plate-reading, and in the therapeutic uses of the roentgen-ray.'

"This requirement has been administered as rigidly as feasible in all of the Council's inspections, correspondence, and dealings with those hospitals. The object was not to make the intern an expert in radiology, but to teach him how to make use of it in his subsequent practice of medicine. In recent years the requirement reads as follows:

"This department must be equipped for at least roentgenographic and roentgenoscopic procedures and must be directed by a physician-roentgenologist who is properly qualified for the work which the department purports to do. Records of the work carried out must be on file in the department, and copies should be filed with the clinical charts.'

"With the establishment of 'Essentials in a Hospital Approved for Residencies in Specialties,' the Council has adopted the following requirements:

"The roentgen-ray laboratory shall be under the direction of a qualified roentgenologist, proficient in the mechanical and interpretative functions of his specialty. He must likewise co-operate in all matters pertaining to the residencies which fall within the purview of his department. The department should contain roentgenologic, roentgenoscopic and, where required, therapeutic equipment.

"Residents in roentgenology or radiology should serve under a specialist who is eligible for inclusion in the list of qualified roentgenologists as prepared by the Council. The laboratory should contain complete diagnostic and therapeutic equipment.'

"The 'Essentials of a Registered Hospital,' established by the Council in 1928, say regarding the radiologic equipment and service in all registered hospitals:

"The hospital should provide or have

ready access to radiologic equipment and service. When a full time or part time physician-roentgenologist cannot be employed, the services of such a consultant should be secured. Radiologic interpretations must be made only by a competent roentgenologist. A description of the roentgenologic examinations should be placed in the patient's chart. The physician-roentgenologist preferably should be one listed by the Council on Medical Education and Hospitals of the American Medical Association.¹

"The foregoing requirements are substantially in harmony with each other and consistent with the requirements of organized radiology. In the interests of uniformity and terminology, some changes are indicated, and such changes probably will be made soon. There is no doubt that the Council will advance its requirements for radiologic service in hospitals as rapidly as demanded by the interests of the public and consistent with the powers and limitations under which the Council works" (4).

V. AMERICAN BOARD OF RADIOLOGY

In 1933, the American Board of Radiology was organized. "On December 9, 1935, the Council on Medical Education and Hospitals officially extended its recognition to this Board under the authority granted to the Council by the House of Delegates; henceforth, the list of diplomates of the American Board of Radiology will take the place of the Council's list of radiologists" (4). This recognition has been a most important one for radiology and has exerted a profound influence upon radiologic standards and education.

The Board of Radiology consists of fifteen radiologists selected from each of the radiologic societies. These men, with the Advisory Committee of the Council on Medical Education and Hospitals, have developed the following qualifications pertaining to education and special training:

"*Professional Education*.—1. Graduation from a medical school of the United

States or Canada, recognized by the Council on Medical Education and Hospitals of the American Medical Association.

"2. Completion of an internship of not less than one (1) year in a hospital approved by the same Council.

"*Special Training*² (to be effective after Jan. 1, 1938).—1. A period of study after the internship of not less than three (3) years in an institution or radiological department recognized by the Council and the Board as competent to provide satisfactory training in the field of radiology.

2. "This period of special preparation shall include:

"(a) Intensive graduate training in pathologic anatomy, radiophysics, and radiobiology.

"(b) An active experience of not less than twenty-four (24) months in a radiological department recognized by the Board and Council as capable of providing satisfactory training.

"(c) Examination in the basic sciences of radiology, as well as in the clinical aspects thereof."

"3. An additional period of not less than two (2) years of study and/or practice."

Since the organization of the Board of Radiology, 849 radiologists have been examined and certified. The members of this Board have given untiringly of their time and thought to the many problems that have confronted them. American radiology owes much to these men and their ceaseless efforts in its behalf.

VI. THE PROGRAM OF THE AMERICAN COLLEGE OF RADIOLOGY IN THE FIELD OF EDUCATION

The fundamental objective of the American College of Radiology is the advancement of the science and practice of radiology to the highest possible plane. Probably the most important element in

² In the case of an applicant whose training has been received outside the United States and Canada, the credentials must be satisfactory to the Advisory Board for Medical Specialties (5).

such a program is education. The College has, therefore, appointed a Commission on Education, whose function is to prepare and present for consideration suggestions relating to medical education. These presentations are made at the regular annual meeting of the College, which is held in Chicago in February. Prepared manuscripts have been given by leaders in medical education at several such meetings.

Under the auspices of the College, an Annual Conference of Teachers in Clinical Radiology was organized at Kansas City, Missouri, May 14, 1936. It is hoped that this yearly conference will stimulate a more active interchange of ideas and lead to the improvement of teaching in radiology in medical schools.

VII. RADIOLOGY IN UNDERGRADUATE MEDICAL EDUCATION

In an effort to obtain concrete data on this subject, questionnaires, requesting certain information, were mailed to every Class A medical institution in the United States and Canada. The following tabulation gives in detail the data collected. The schools that did not return their questionnaires had to be omitted.

STATISTICS AS REGARDS RADIOLOGY IN RECOGNIZED MEDICAL SCHOOLS IN THE UNITED STATES AND CANADA

ALABAMA

University of Alabama School of Medicine, Tuscaloosa. Two-year course only. Prof. J. A. Maxwell, M.D., gives two sessions in second year of Anatomy to introduce Radiology.

ARKANSAS

University of Arkansas School of Medicine, Little Rock. In third year, 11 hours of General Roentgenology; in fourth year, 22 hours of Clinical Roentgenology. Radiology is rated with other medical specialties. It is included in the Division of Medicine and Medical Specialties. D. A. Rhinehart, M.D., is Professor of Roentgenology; Barton A. Rhinehart, M.D., is Associate Professor.

CALIFORNIA

University of California Medical School, Berkeley and San Francisco. In first year, 10 lectures on Radiology as applied to the teaching of Anatomy; in second year, one hour per week with Pathology for one semester, or 15 hours; in third year, eight lectures as part of General Surgery, eight informal confer-

ences and discussions with Surgery, study of x-rays of own medical patients; in fourth year, two hours per week for ten and two-thirds weeks during General Surgery assignment, also x-ray study of own patients. Radiology is rated on a par with specialties; a sub-department of Surgery. Howard E. Ruggles, M.D., Clinical Professor of Roentgenology, is head of Sub-department.

University of Southern California School of Medicine, Los Angeles. In first year, six hours demonstration of x-ray films in connection with Anatomy; in second year, 12 hours fluoroscopic examination of gastrointestinal tract in Physiology and of chest in Physical Diagnosis, study of films with patients in groups of 24; in third year, from 43 to 50 lectures, demonstrations, and conferences; in fourth year, no formal course other than viewing films of out-patient department (12 hours). Radiology serves all departments and can hardly be compared to other specialties. It is included in the Department of Medicine. Ray A. Carter, M.D., Associate Professor of Clinical Medicine, is in charge.

Stanford University School of Medicine, San Francisco.

In first year, the x-ray is used a little in teaching Anatomy and Physiology; in second year, 10 hours (Medicine 203), Radiology, Physics of Radiation; in third year, 33 hours (Medicine 213), clinical radiological conferences; in fourth year, 44 hours required, 41 hours elective (Medicine 213, Medicine 3—Radiology, Medicine 4—Fluoroscopy, Medicine 12—Advanced Radiology, Surgery 211—Tumor Clinic, Pathology 3—Oncology). (Information derived from letter.) Radiology is rated on a par with the specialties; included in Department of Medicine. R. R. Newell, M.D., Professor of Medicine, is in charge.

COLORADO

University of Colorado School of Medicine, Denver. In first year, films are used in teaching Gross Anatomy; in second year, Radiology is incidental to Medicine and Surgery; in third year, 31 hours are devoted to Roentgenology; in fourth year, 31 hours (elective) are devoted to Roentgenology. It is rated with the Division of Surgery, and Ernst A. Schmidt, M.D., Associate Professor of Surgery, is in charge of Radiology.

CONNECTICUT

Yale University School of Medicine, New Haven. In first and second years, no Radiology is taught; in third year, an introductory course is required (small groups one-half trimester, one hour per week for five and one-half weeks, Clinical Medicine 110, Radiology); in fourth year, elective, groups limited to six students, two hours, three times per week, for five and one-half weeks, Radiology 120. (See Bulletin, pp. 106 and 113.) Sect. of Radiology, Div. of Surgery, W. H. Wilson, M.D., Assistant Professor of Radiology.

DISTRICT OF COLUMBIA

Georgetown University School of Medicine, Washington, D. C. In first year, two hours per week, Anatomy as shown by x-ray; in second year, one hour per week, Physiological Processes as shown by x-ray; in third year, two hours per week during one-half year, 10 hours each section X-ray Pathology; in fourth year, 15 hours Radiology. Radiology is rated on a par with Medicine and Surgery as a separate department of which F. O. Coe, M.D., Professor of Radiology, is head of Department.

George Washington University School of Medicine, Washington, D. C. In third year, Radiology is an elective course, one hour per week for 16 weeks (Radiology and Radiotherapy). It is rated on a par with other specialties; included in Department of Medicine, under W. A. Bloedorn, M.D., Professor of Medicine.

Howard University College of Medicine, Washington, D. C. In third year, 22 hours instruction in Roentgenology. In Department of Surgery, under an instructor in roentgenology.

GEORGIA

University of Georgia School of Medicine, Augusta. In fourth year, 66 hours instruction in Radiology. (See Bulletin, p. 53.) On a par with the other specialties. L. P. Holmes, M.D., Professor of Clinical Roentgenology; G. T. Bernard, M.D., Professor of Clinical Surgery and Dermatology (Radium Therapy), are in charge of Department.

ILLINOIS

Loyola University School of Medicine, Chicago. In first year, anatomical demonstrations by x-ray; in second year, 12 hours, not including special demonstrations of x-rays in Physiology; in third year, 36 hours of lectures and lantern demonstrations and from 12 to 24 hours in small sections at various hospitals; in fourth year, from 4 to 12 hours to each section at various hospitals in correlation with Clinical Surgery, Diagnosis, and Out-patient Department. Radiology is on a par with the other specialties. Benjamin H. Orndoff, M.D., Professor of Radiology, is in charge of Department.

Northwestern University Medical School, Chicago. In first year, from 40 to 44 hours (two hours per week for two quarters), Radiological Anatomy; in second year, no set hours, but requested in Physiology and Pathology; in third year, 33 hours (one hour per week for three quarters), textbook, Radiological Didactics; in fourth year, 36 hours approximately, dispensary study of Radiology. (See Bulletin, pp. 20 and 47.) Radiology is on a par with the other specialties; a division of Department of Surgery. James T. Case, M.D., Professor of Radiology, is in charge of Division.

University of Chicago, Rush Medical College, Chicago. In third year, 33 hours in Surgery (and another course of 24 hours), and 26 hours in Pediatrics; in fourth year, two courses of 24 hours each in Surgery and 6 hours in Pediatrics. Radiology is included in the Department of Surgery. V. C. David, M.D., Chairman, Department of Surgery; F. H. Squire, M.D., Assistant Clinical Professor of Surgery (Radiology), are in charge.

University of Chicago, The School of Medicine of the Division of the Biological Sciences, Chicago. In third year, one and one-half hours per week for one year (Roentgenology), seminar plus ward rounds and x-ray viewing room; in fourth year, 22 hours in Autumn quarter (Roentgenology), lectures plus continuation of third year work. Radiology is on a par with Medicine and Surgery; technically in the Division of Medicine but practically separate. Paul C. Hodges, M.D., Professor of Roentgenology, is in charge.

University of Illinois College of Medicine, Chicago. In first year, approximately 16 hours as part of Anatomy; in second year, approximately four hours as part of Physiology; in third year, no time allotted but in near future will be incorporated with Pathology; in fourth year, 32 hours didactic work, with slide demonstrations (16 hours), each semester. An optional course is offered in film interpretation (12 hours), dispensary practice, with technic, diagnosis, and therapy. Radiology is on a par with the other specialties. Separate department, of which Adolph Hartung, M.D., Professor of Roentgenology, is head.

INDIANA

Indiana University School of Medicine, Bloomington and Indianapolis. In first year, normal radiographs of bony parts are shown in Osteology and Anatomy; in third year, clinical and dispensary work, clinical conferences; in fourth year, roentgen diagnosis and radiotherapy. Radiology is included in Division of Medicine. R. C. Beeler, M.D., Professor of Radiology, is in charge of Division.

IOWA

Slate University of Iowa College of Medicine, Iowa City. In first year, stock films are used in Anatomy to demonstrate bone relations; in second year, one demonstration of normal flow of barium through the gastro-intestinal tract; in third year, 32 hours, two semesters, roentgen interpretation, lectures, and slides; in fourth year, 16 hours in second semester (as elective) Roentgen Interpretation; also six lectures on therapy. (See Bulletin, pp. 305, 306.) Radiology is in the Division of Medicine, probably classed as one of the specialties. H. D. Kerr, M.D., Professor of Radiology, is in charge of Department.

KANSAS

University of Kansas School of Medicine, Lawrence, Kans., and Kansas City, Kans. In third year, 18

hours of didactic elementary roentgenology and eight hours of clinical work in groups of 8; in fourth year, 22 hours of clinical work, 22 hours (elective) clinical roentgenology as applied to medicine, diagnostic and clinical roentgenology, and the practice of roentgenology. Radiology is on a par with the other specialties in the Division of Medicine. G. M. Tice, M.D., Assistant Professor of Radiology, is in charge of Department.

KENTUCKY

University of Louisville School of Medicine, Louisville. In first year, fluoroscopic demonstrations of chest and abdomen by professor of anatomy; in second year, fluoroscopic examinations and demonstrations of chest and abdomen and use of barium meal before small groups; in third year, 24 hours didactic lectures on Radiology, with lantern slides; in fourth year, 18 hours radiation therapy, with applications, and ward rounds of cancer patients. Radiology is a branch of the Division of Surgery. D. Y. Keith, M.D., Instructor in Radiology, is in charge.

LOUISIANA

Louisiana State University Medical Center, New Orleans. In fourth year, 14 hours of instruction in Radiology. On a par with the other specialties, in Division of Surgery. Amédée Granger, M.D., Professor of Radiology, is in charge.

Tulane University of Louisiana School of Medicine, New Orleans. In second year, general lectures with Pathology and Medicine; in third year, 19 hours to a group which rotates, in Diagnostic Roentgenology; in fourth year, eight hours to a group which rotates, in Radiation Therapy. Six general lectures Radiology to combined third- and fourth-year classes; radiological conferences each morning for one hour to third- and fourth-year classes; graduate teaching in Radiology formerly given in post-graduate school now given in undergraduate school. Radiology is on a par with other specialties, in Department of Medicine. Leon J. Menville, M.D., Professor of Radiology, is in charge.

MARYLAND

University of Maryland School of Medicine and College of Physicians and Surgeons, Baltimore. In fourth year, two hours instruction per week in Roentgenology. (See Bulletin, p. 49.) Radiology is on par with other specialties in Sub-department of Surgery. H. J. Walton, M.D., Professor of Roentgenology, is in charge.

MASSACHUSETTS

Boston University School of Medicine, Boston. In first year, five hours of clinical correlation exercises; in third year, 16 hours Roentgenology (elective), five hours clinical correlation, 28 hours x-ray conferences; in fourth year, 18 hours Clinical Radiology. Radiology is a specialty under Department of Surgery. The assistant professor of roentgenology is in charge.

Harvard University Medical School, Boston. In first year, one hour lecture-demonstration to explain purpose and value, routine chest films with tuberculin test of first- and fourth-year students; in third year, 12 hours, in groups of 16 students (not a separate course); in fourth year, one month, all day (elective), Medicine IX. One-third of class of 125 take the course. Clinical conferences, x-ray seminar, etc. Radiology is under the Department of Medicine but is not rated on a par with other specialties. George W. Holmes, M.D., Clinical Professor of Roentgenology, is in charge.

Tufts College Medical School, Boston. In second year, 15 hours clinical lectures in Radiology; in third year, 16 hours of roentgen interpretation; in fourth year, one month daily (elective) in one of three hospital radiological departments. Radiology is held to be independent of, but correlated to, Departments of Medicine and Surgery. F. W. O'Brien, M.D., Professor of Radiology, is head.

MICHIGAN

University of Michigan Medical School, Ann Arbor. In first year, no specific number of hours is allotted to Radiology, studied as an adjunct to Anatomy; in second year, 16 hours (elective), No. 120, introduction to Roentgenology and Physical Therapy; in third year, 32 hours, No. 130, Principles of Roentgenology and Physical Therapy, also 32 hours, No. 131, Junior section in Clinical Roentgenology and Radiation Therapy; in fourth year, approximately 32 hours, adjunct to other clinical subjects. (See Bulletin, pp. 95, 96.) Radiology is rated on a par with Medicine and Surgery; separate department. F. J. Hodges, M.D., Professor of Roentgenology, is head.

Wayne University College of Medicine, Detroit. In first year, in conjunction with Anatomy, five to ten hours demonstration of normal films (not a separate course); in second year, five to ten hours in conjunction with Physiology; in third year, one hour per week for twelve weeks of lectures and demonstrations; in fourth year, three hours per week for twelve weeks of lectures and clinical work. Radiology is rated on a par with other specialties, in the Division of Medicine. J. C. Kenning, M.D., Professor of Roentgenology, is in charge.

MINNEAPOLIS

University of Minnesota Medical School, Minneapolis. In first year, four hours lectures and demonstrations to sections (elective) on Roentgenology of Normal Anatomy; in second year, 11 hours on Biophysics; in third year, 33 hours lectures (elective) on Radiology including diagnosis and therapy; in fourth year, 11 hours lectures, three hours per week demonstrations and clinics in Roentgen Diagnosis. Radiology is rated on a par with Medicine and Surgery,

in separate department. Leo G. Rigler, M.D., Professor of Radiology, is head.

MISSOURI

St. Louis University Medical School, St. Louis, Mo. In first year, fluoroscopic demonstrations to classes in Anatomy; in second year, demonstrations in association with lectures on Physiology; in third year, 32 didactic lectures and demonstrations of one and one-half hours each; in fourth year, individual sections on Clinical Roentgenology, one hour lecture and demonstration each week throughout school year. Radiology is rated on a par with the other medical specialties, in separate department. L. R. Sante, M.D., Professor of Radiology, is head.

Washington University School of Medicine, St. Louis, Mo. In fourth year, four hours per week for trimester Radiology (elective). Radiology is rated on a par with other specialties, in separate department. Sherwood Moore, M.D., Professor of Radiology, is head.

NEBRASKA

Creighton University School of Medicine, Omaha, Nebraska. In first year, 10 hours Anatomy and Physiology; in second year, 11 hours lectures, demonstrations, and conferences X-ray Fundamentals; in third year, 22 hours lectures, demonstrations, and conferences, one hour per week for year (dispensary, in sections) Principles and Practice of Radiation and Physical Therapy; one hour per week to sections for one year (11 hours to each section), practice work in the hospital and dispensary, Radiological Methods of Examination. Radiology is rated on a par with other specialties, included in Department of Surgery. J. F. Kelly, M.D., Professor of Radiology and Physiotherapy, is in charge.

University of Nebraska College of Medicine, Omaha. In second year, 16 lectures (one-half hour credit) Principles of Radiology; in third year, four ward rounds therapy section, 16 conferences (one-half hour credit) Clinical Radiology; in fourth year, occasional (elective) instruction, eight lectures and demonstrations (one-hour credit) Roentgen Technic. Radiology is rated on a par with other specialties; separate department. H. B. Hunt, M.D., Associate Professor of Radiology (to be Professor next year), is in charge.

NEW HAMPSHIRE

Dartmouth Medical School, Hanover. In first year, Radiology is used in teaching Anatomy and Physiology; in second year, in teaching Diagnosis and Surgery. Radiology exists as a docentship. L. K. Sycamore, M.D., Docent in Roentgenology, is in charge.

NEW YORK

Albany Medical College, Albany. In third year, 16 hours to whole class, 15 hours to each one-sixth, Roentgenology; in fourth year, instruction in con-

junction with medical and surgical clinics and in Physical Diagnosis. Radiology is on a par with other specialties; included in Department of Surgery. W. P. Howard, M.D., Clinical Professor of Roentgenology, is in charge.

Long Island College of Medicine, Brooklyn. In first year, 10 hours with Anatomy; in second year, four hours with Physiology; in third year, no specific hours, in conjunction with Medicine, Surgery, and Pediatrics; in fourth year, 60 hours. Radiology is rated on a par with other specialties, included in Department of Medicine, under the professor of Clinical Radiology.

Cornell University Medical College, Ithaca and New York City. In third year, eight hours Radiology; in fourth year, free time may be spent on the subject. Radiology is not rated with the other specialties; separate department. H. M. Imboden, M.D., Professor of Clinical Radiology, is head.

Columbia University College of Physicians and Surgeons, New York City. In first year, films being assembled to teach Anatomy; in third year, 25 hours for demonstrations of malformations in informal section in X-ray Department; in fourth year, 16 hours to groups of 12, two lectures on Radiotherapy, film-reading. (See Bulletin, p. 61.) Radiology is rated on par with other specialties; separate department. Ross Golden, M.D., Professor of Radiology, is head.

New York Medical College and Flower Hospital, New York City. In first year, 12 hours in conjunction with Anatomy, Roentgenology, normal bone and viscera demonstrations; in second year, 12 hours Roentgenology, demonstrations of pathologic conditions; in third year, 12 hours X-ray and Radium Therapy; in fourth year, 12 hours to each student (instruction given in sections), clinical demonstrations of radiologic conditions. Radiology is rated equal with other specialties; separate department. J. Campbell Howard, M.D., Professor of Radiology, is head.

New York University College of Medicine, New York City. In first year, 10 hours lectures, 10 hours section work per student in X-ray Anatomy; in second year, three hours lectures, three hours section work per student in X-ray Physiology, 10 hours lectures on Pathologic Basis of X-ray Diagnoses, two elective courses (one month, 20 lessons) in Normal Anatomy, Variations and Congenital Malformations, Physics of Radiology; in third year, 16 hours practical demonstrations to each student of X-ray Diagnosis, five hours lectures on Radiation Therapy; in fourth year, two elective courses (six hours per week for four weeks) in General X-ray Diagnosis, an elective course on Gastro-intestinal Tract, an elective course on Bones, and an elective course on Thorax. Radiology

is a special department. I. Seth Hirsch, M.D., Professor of Radiology, is in charge.

University of Rochester School of Medicine, Rochester. In first year, demonstration of films of bony structures and circulation; in second year, eight hours demonstration of gastro-intestinal tract and heart, fluoroscopy of chest to check physical diagnosis; in third year, one hour per week for year of formal instruction in interpretation of films; in fourth year, one hour per week throughout year of formal instruction. Radiology is rated on a par with Dermatology but has a larger budget; included in Department of Medicine. S. L. Warren, M.D., Associate Professor of Medicine, in charge of Division of Radiology.

Syracuse University College of Medicine, Syracuse. In third year, one hour per week during first semester, Radiology; in fourth year, one hour per week during entire year, Radiology and radiologic conferences. Radiology is rated on a par with Medicine and Surgery; special department. Donald S. Childs, M.D., Professor of Clinical Radiology, is head. Radiology is not taught as a separate science but in relation to and use in diagnosis and treatment.

NORTH CAROLINA

University of North Carolina School of Medicine, Chapel Hill. This is a two-year school.

Duke University School of Medicine, Durham. In first year, x-ray skeleton in Department of Anatomy; in second year, eight hours each quarter, principles of X-ray Diagnosis; in third year, consultation on clinical cases; in fourth year, 48 hours lectures, 72 hours tumor clinics, Roentgen Diagnosis. Radiology is rated on a par with Medicine and Surgery; separate department. R. J. Reeves, M.D., Professor of Radiology, is head.

NORTH DAKOTA

University of North Dakota School of Medicine, Grand Forks. This is a two-year school; no department.

OHIO

University of Cincinnati College of Medicine, Cincinnati. In first year, one hour per week during one semester Radiology, eight hours Anatomy; in second year, one hour per week during one semester Radiology with Pathology and Physiology (eight hours); in third year, one hour per week during one semester (one-fourth of class in each section) interpretation of films (eight hours); in fourth year, one hour per week during one semester (elective) General Radiology (16 hours). (See Bulletin, pp. 41-44, 56.) Radiology is rated on a par with other specialties; separate department. Sidney Lange, M.D., Professor of Radiology and Radiotherapeutics, is head.

Western Reserve University School of Medicine, Cleveland. In third year, 16 hours Roentgenology; in

fourth year, four hours in groups and four weeks in optional clerkship in Roentgenology. Radiology is rated on a par with other specialties, included with Pathology. Eugene Freedman, M.D., Assistant Professor of Roentgenology, is in charge.

Ohio State University College of Medicine, Columbus. In fourth year, six hours X-ray Physics and Therapy. Radiology is not rated on a par with other specialties, included in Department of Surgery. H. J. Means, M.D., Associate Professor of Surgery, instructs in Roentgenology.

OKLAHOMA

University of Oklahoma School of Medicine, Oklahoma City. In first year, Radiology is taught in conjunction with Anatomy and Physics; in second year, in conjunction with Physical Diagnosis; in third year, x-ray instruction in out-patient department of hospital; in fourth year, 16 hours lectures and demonstrations in Diagnostic Roentgenology, 16 hours lectures and demonstrations in Therapeutic Radiology, practical demonstrations in Cardiology, Gastro-intestinal Examination, Urology and (elective) Orthopedics. (Bulletin contains no outline of course.) Radiology is rated on a par with other specialties; separate department. The professor of radiology is the head of the department.

PENNSYLVANIA

Hahnemann Medical College and Hospital of Philadelphia. In first year, no instruction in Radiology except in General Physics; in third year, 30 hours didactic instruction, 10 hours Clinical Roentgenology; in fourth year, five hours in sectional conferences. Radiology is a separate section under Materia Medica and Therapeutics. J. W. Frank, M.D., Professor of Roentgenology, is in charge.

Jefferson Medical College of Philadelphia. In first year, two hours in Anatomy; in second year, one hour per week during whole term Roentgenology (six hours); in third year, one hour per week after Christmas (20 hours) Roentgen Diagnosis and Therapy. Radiology is considered as a specialty; separate department. W. F. Manges, M.D., deceased, was head of the department.

Temple University School of Medicine, Philadelphia. In first year, 50 hours Anatomy as Revealed by Roentgen Ray; in second year, four to five hours Physiology as Revealed by Roentgen Ray and Physical Diagnoses Checked by Roentgen Ray; in third year, 20 hours Pathology as Revealed by Roentgen Ray; in fourth year, 40 hours clinical radiological conferences (clinical radiological sections of six students, five hours). Radiology is rated on a par with Medicine, Surgery, Anatomy, etc., but undergraduate courses in Radiology are minors. Separate department, of which W. E. Chamberlain, M.D., Professor of Radiology, is the head.

University of Pennsylvania School of Medicine, Philadelphia. In first year, instruction in Radiology is included in Anatomy and Physiology; in second year, included in Pathology; in third year, 16 hours to entire class didactic elementary course in Radiology; in fourth year, 40 hours in small groups, conferences, round table discussions, and ward classes. Radiology is rated on a par with other specialties; separate department, of which H. K. Pancoast, M.D., Professor of Radiology, and E. P. Pendergrass, M.D., Professor of Radiology, are heads.

Woman's Medical College of Pennsylvania, Philadelphia. In first year, 24 hours demonstrations relating to anatomy; in second year, six hours Roentgenologic Technic and appearances of limbs and viscera; in fourth year, 14 hours lectures and demonstrations in Roentgenology. Radiology is not rated on a par with other specialties and fewer hours are devoted to it. Separate department, of which Jacob Vastine, M.D., Clinical Professor of Radiology, is head.

University of Pittsburgh School of Medicine, Pittsburgh. In third year, eight hours Roentgenology; in fourth year, 31 hours Roentgenology. Radiology is rated on a par with other specialties. Separate department, of which G. W. Grier, M.D., Professor of Radiology, is head.

SOUTH CAROLINA

Medical College of the State of South Carolina, Charleston. In first year, demonstrations of normal anatomy in conjunction with Anatomy; in second year, demonstrations in conjunction with Pathology; in third year, 32 lectures and demonstrations on Radiology and Electrotherapy (elective course); in fourth year, films, fluoroscopic examinations, and treatment demonstrations. Radiology is rated on a par with Dermatology, Otolaryngology, etc.; sub-department of Medicine. Hillyer Rudisill, Jr., M.D., Professor of Radiology and Electrotherapy, is in charge.

SOUTH DAKOTA

University of South Dakota School of Medicine, Vermillion. Only two-year medical course given.

TENNESSEE

University of Tennessee College of Medicine, Memphis. In second year, 22 hours Roentgenology (401); in third year, included in various courses; in fourth year, 22 to 33 hours Roentgenology (602). Radiology is rated on a par with other specialties; separate department, of which W. S. Lawrence, M.D., Professor of Roentgenology, is head.

Meharry Medical College, Nashville. In first year, eight hours Osteology; in fourth year, 32 hours didactic work and clinics in groups, two hours per week, Roentgenology. Radiology is rated as a

lecture course; included in Department of Medicine. H. S. Shoulders, M.D., Professor of Roentgenology, is in charge.

Vanderbilt University School of Medicine, Nashville. In third year, 26 hours Roentgenology; in fourth year, 13 hours Radiology, 90 hours Roentgen Diagnosis, 26 hours X-ray Technic. (See Bulletin, p. 118.) Radiology is rated on a par with Medicine and Surgery; separate department, of which C. C. McClure, M.D., Associate Professor of Radiology, is head.

TEXAS

Baylor University College of Medicine, Dallas. In fourth year, 30 hours, Diagnosis, 30 hours Tumor Clinic, Radiology-Tumor Clinic. Radiology receives ample recognition; included as part of Surgical Department but really independent. J. M. Martin, M.D., Professor of Radiology, and C. L. Martin, M.D., Professor of Radiology, are co-equally in charge.

University of Texas School of Medicine, Galveston. In first year, Radiology is employed in the study of bones, the thorax and gastro-intestinal tract in conjunction with Anatomy; in third year, one lecture per week for 14 weeks Radiology; in fourth year, one lecture per week for 14 weeks, combined with demonstration, Radiology. (See Bulletin, pp. 48, 49.) Radiology is rated as a minor subject on a par with medical specialties. Separate department of which J. B. Johnson, M.D., Associate Professor of Radiology, is head.

UTAH

University of Utah School of Medicine, Salt Lake City. In second year, 12 hours X-ray Anatomy. Two-year medical course only.

VERMONT

University of Vermont College of Medicine, Burlington. In second year, six hours Roentgenology (four hours in Pathology on Tumor Therapy); in third year, six hours Roentgenology; in fourth year, 10 hours Roentgenology. Radiology is rated among the minor specialties. A separate department, but much teaching in conjunction with Departments of Medicine, Surgery, and Pathology. A. B. Soule, Jr., M.D., Instructor in Roentgenology, is in charge.

VIRGINIA

University of Virginia Department of Medicine, Charlottesville. In first year, occasional lectures and demonstrations in Anatomy; in second year, no special hours but demonstrations of clinical cases in Physical Diagnosis; in third year, demonstrations in connection with clinical cases; in fourth year, 20 hours didactic course, Roentgenology. Radiology is rated essentially on a par with major departments. Separate department, of which Vincent Archer, M.D., Professor of Roentgenology, is head.

Medical College of Virginia, Richmond. In first year, film demonstrations in Anatomy (Anatomy I); in second year, film demonstrations in Pathology (Pathology I); in third year, 16 hours first half-year, 16 hours in sections second half-year (Radiology I and II). Radiology is rated on a par with other specialties. Professional equality on faculty and hospital boards with Medicine and Surgery. Separate department, of which F. B. Mandeville, M.D., Professor of Radiology, is head.

WEST VIRGINIA

West Virginia University School of Medicine, Morgantown. In first year, instruction is occasionally given in connection with Anatomy. This is a two-year school.

WISCONSIN

University of Wisconsin Medical School, Madison. In third year, 16 hours Radiography and Radiotherapy; in fourth year, four one-half day periods Applied Radiology. Radiology is rated on a par with other specialties. Separate department, of which E. A. Pohle, M.D., Ph.D., Professor of Radiology, Chairman of Department of Radiology and Physical Therapy, is head.

Marquette University School of Medicine, Milwaukee. In first year, 30 hours as part of Gross Anatomy; in second year, 30 hours as part of Living Anatomy and Pathology; in third year, 15 hours Roentgenology; in fourth year, 16 hours Roentgenology. (See Bulletin, pp. 53, 54.) Radiology is rated on a par with other specialties. Separate division under Surgery. F. W. Mackoy, M.D., Clinical Professor and Director of Division of Roentgenology, is in charge.

CANADA

Dalhousie University Faculty of Medicine, Halifax, N.S. In third year, 30 hours Radiology. Radiology is not rated on par with Medicine, Surgery, or specialties. Separate department, of which S. R. Johnston, M.B., Lecturer, is in charge.

University of Western Ontario Medical School, London, Ont. In fifth year, 30 hours; in sixth year, 15 hours, extra demonstrations, Department of Radiology. (See Bulletin, p. 50.) Radiology is rated on a par with all other departments. Separate department, of which George McNeill, M.B., Professor of Radiology, is head. This school has a six-year medical course.

University of Toronto Faculty of Medicine, Toronto, Ont. In second year, Radiology is taught as part of Anatomy; in fifth year, 10 hours each trimester; in sixth year, 20 hours each trimester. (See Bulletin, pp. 39, 40, and 80.) Radiology is "not actually on a par with Medicine and Surgery, but is outwardly." Separate department, of which G. E. Richards, M.B.,

Professor of Radiology, is head. This school has a six-year medical course.

McGill University Faculty of Medicine, Montreal, Que. In fifth year, instruction in Radiology is given. Radiology is not on a par with other specialties. It is not a separate department; a lecturer gives instructions. This school has a six-year medical course.

University of Montreal Faculty of Medicine, Montreal, Que. In first year, 15 hours fundamental principles, 30 hours practical work in Radiology; in second year, 15 hours more advanced theoretical lectures in Radiology; in third year, 10 hours Radiodiagnosis and Radiotherapy; in fourth year, 10 hours Radiodiagnosis and Radiotherapy. Radiology is rated on a par with Medicine and Surgery. Separate department, of which J. E. Gendreau, M.B., is Titular Professor.

True to my expectations, there is a wide variation in the amount of time allocated to radiology, to its utilization in teaching such subjects as anatomy, physiology, pathology, and physical diagnosis, and also in clinical conferences. It has seemed to me, however, as I have read and studied the data, that such a variance is a particularly stimulating situation, especially if the College of Radiology continues to sponsor the Annual Conference of Teachers of Radiology so that all may benefit by an exchange of ideas. Since there is such a tremendous difference in the methods of teaching a preclinical subject, anatomy, for example, and the clinical subjects of medicine and surgery, it is small wonder that radiologists are often at a loss as to just how their specialty should be taught. It was necessary to read only a few of the letters accompanying the answers to our questionnaire to find many real problems. These varied from lack of an adequate budget and personnel to allocation of sufficient time in an already overcrowded curriculum. Some teachers, in schools where considerable time is devoted to radiology, very properly raised the question as to whether the student may be failing to develop other diagnostic methods. Others, in schools where little recognition has been given to radiological methods in the past, felt an increasing need for such methods in the

teaching of preclinical courses. All schools agreed, generally, that radiology should be presented to the undergraduate with the idea of making a good general practitioner and not a specialist. Since radiology serves every branch of medicine and almost every research problem, the student should, necessarily, have some understanding of normal and pathologic processes as they appear in the roentgenogram. Furthermore, irradiation, either by roentgen or radium therapy, is used so extensively in the treatment of neoplastic disease and certain infections that a physician is tremendously handicapped if he cannot intelligently approach such a consideration with his patient.

Anatomy.—The majority of the four-year medical schools are using roentgenograms and fluoroscopic observations in connection with the teaching of anatomy, although very few two-year schools follow this method. Unfortunately, the information available at this time is insufficient to permit one to present a comprehensive outline of the methods used. Some schools give in excess of fifty hours of anatomy as revealed by radiologic methods; others, only one or two lectures and several fluoroscopic examinations. Demonstrations include osseous and epiphyseal development; movement of joints; roentgenograms of soft tissues; the injected arterial and venous circulation; the cerebrospinal fluid pathways after replacement of the fluid by air; the genital organs in the female after injection with opaque oils; the urinary and biliary tracts after the use of dyes to render their lumens visible, and the respiratory and gastro-intestinal systems. Fluoroscopic examinations include observations of joint movements and the respiratory and gastro-intestinal tracts. In some institutions, all the radiologic work is done by the instructors in anatomy; in others, assistance is given by the radiologists. When radiologic observations are correlated with dissection, the course becomes one that can properly be termed "living anatomy or physiology."

Physiology.—Very few schools use roent-

gen methods as an adjunct in teaching physiology. Two schools devoted one hour per week throughout the year. With small groups, fluoroscopic consideration is given to the physiology of the respiratory and the gastro-intestinal tracts, and the cardio-vascular system. Roentgenograms, made after the administration of dye, are used in the demonstration of the physiology of the biliary and urinary tracts.

Several schools give a course in biophysics, which, in at least one instance, is allocated fifteen hours for the microscopic study of the effect of radiation on tissues.

Pathology.—A great many schools have courses that are variously designated "X-ray Pathology," "Pathology, as Seen in the Roentgenogram," etc. Quite a few schools using radiologic methods in teaching anatomy do not use it in teaching pathology, and *vice versa*. At least one institution has an excellent x-ray museum, which is available for teaching anatomy, physiology, and pathology to small groups.

Physical Diagnosis.—Relatively few institutions use either roentgenograms or fluoroscopic observations to teach their students physical diagnosis. It seems to me that, if radiologic methods were properly applied, it would assist in stimulating the student to improve his inspection, percussion, palpation, and auscultation. I feel there is a real opportunity here to foster the student's ability. You, as I, have doubtless marveled at the skill of those clinicians who have trained their eyes, ears, and palpating fingers to such an extent that their reports are usually confirmed, rather than made, by the appropriate roentgen examination. Such precision was obtainable, formerly, only by careful correlation of the physical findings with those of either operative or postmortem examinations. At the present time, unfortunately, there seems to be an increasing tendency to depend entirely upon the roentgen examination for diagnosis, instead of using it as a check and improvement of other diagnostic methods.

Clinical Radiology.—Radiology is taught during the third and fourth years in almost

every school of medicine. There may be didactic lectures; clinico-radiologic conferences, pathologico-radiologic conferences; trimester clerkships, during which students accompany their patients throughout radiologic examinations; roentgenogram demonstrations, to small groups; elective courses in respiratory or gastrointestinal tract diseases; tumor conferences, and various combinations of the above methods. The conferences, which are very popular with, and apparently very profitable to, the students, seem to be a method of instruction acceptable alike to most radiologists and clinicians.

No statement of hours, or catalogue tabulations, could give an adequate idea of the instruction in radiology of the various medical schools. In the vast majority, instruction seems adequate; in others, either lacking or topheavy. With so many different methods of approach to one subject, there is much to be gained from an interchange of opinions. In no instance did I obtain the impression that the radiologist was trying to further the interests of either himself or his specialty. On the other hand, the radiologist seemed to have an earnest desire to assist in teaching the student to be a better doctor. In most medical schools, there seemed to be an excellent *esprit de corps* between the radiologists and other departmental heads. Co-operation, of course, is an essential feature in any comprehensive plan of medical education.

SYNOPSIS OF STATISTICS FROM QUESTIONNAIRES RETURNED FROM 74 RECOGNIZED MEDICAL SCHOOLS IN THE UNITED STATES AND CANADA CONCERNING UNDERGRADUATE INSTRUCTION IN RADIOLOGY

Length of Course (Medical).—Two years, 6; four years, 65; six years, 3.

Instruction in Radiology.—Given in 71 schools.

Department of Radiology.—Separate, 38 schools; under Surgery, 15 schools; under Medicine, 13 schools; under Pathology, 1 school; no department, 7 schools.

College Rank of Teacher.—Professor, 50

schools; Associate Professor, 8 schools; Assistant Professor, 4 schools; Instructor, 4 schools; Lecturer, 2 schools.

First-year Instruction.—Given in 39 schools; usually taught in conjunction with Anatomy.

Second-year Instruction.—Given in 39 schools, generally in conjunction with Physiology and Pathology.

Third-year Instruction.—Given in 56 schools; 20–30 hours didactic lectures; some seminar or clinical conferences, ward rounds, etc.

Fourth-year Instruction.—Given in 59 schools; 30–40 hours (some as low as 10 hours, others as high as 60 hours); course often optional or in correlation with outpatient department; some practical application of theory; interpretation of films, etc.

Six-year Courses.—One school, fifth and sixth years; one school, second, fifth, and sixth years; one school, fifth year only.

Clinical Conferences.—Thirty - three schools.

Elective Courses.—Fifteen schools.

The above statistics indicate that there has been a tremendous increase in the use of radiology in teaching during the last few years. Such information is encouraging, but, at the same time, carries with it an enormous obligation, which we, as radiologists, should strive to fulfill. To comprehend the situation more fully, compare the present statistics with those of Hickey (6), who states that prior to 1900, radiology was taught to undergraduates in only one college in America; from 1900–1910, in 15 colleges; 1910–1920, in 20 colleges, and 1920–1928, 52³ colleges.

VIII. GRADUATE INSTRUCTION IN THE SPECIALTY OF RADIOLOGY

The requirements for training the physician who desires to become a specialist in radiology are general and inclusive, but not specific. This lack of specific requirements

³ Hickey's original article states only eight, but this number is obviously incorrect since data were collected from 52 institutions.

is, in many ways, a distinct asset. No one knows, at present, just how many institutions can fulfill the regulations of the Council on Medical Education. Likewise, the Council, itself, in setting up the specifications for Graduate Education, has placed a broad interpretation upon its requirements, since there are very few teachers who agree as to the precise methods and subjects to be taught. It will necessitate many years of careful thought, experience, and interchange of ideas before an ideal can be formulated.

Kirklin (5), Secretary of the American Board of Radiology, feels that judicious selection of the graduate students is of prime importance. It is his belief that the minimum three years of the course should be apportioned as follows:

"Six (6) months to pathologic anatomy; three (3) months to roentgenologic technic; twelve (12) months to roentgenologic diagnosis, and nine (9) months to radiotherapy, leaving six (6) months for the student to allot at will to any branch in which he is particularly interested or feels that he is deficient. If the course is arranged on the quarter system and students are admitted at the beginning of any quarter, the order in which the different branches are taken up may vary. However, special instruction in pathologic anatomy is so fundamentally essential for rational diagnosis and treatment that it should be given as early as possible.

"During his intensive review of pathologic anatomy, the student should have an opportunity not only to study the gross and microscopic pathology of specimens obtained at operation or necropsy, but also to compare the morbid conditions with the antecedent roentgenologic manifestations, and to observe at first-hand the effects of irradiation on normal and abnormal tissues. Occasionally it is desirable to subject cadavers to roentgenography before necropsy, and the necessary equipment should be available for this purpose. Roentgenography of removed specimens also is sometimes instructive. While the student is pursuing his studies in morbid anatomy, he should be encouraged to investigate some special radiopathologic problem as a theme for research.

"Instruction in roentgenologic diagnosis should begin with an active apprenticeship of three (3) months in the technic of roentgenography and the development of roentgeno-

grams. No matter how many technicians the practising radiologist may have to perform these duties for him, he will be gravely handicapped if he has not learned how to execute them himself. Not less than twelve (12) months of close observation and experience in roentgenologic diagnosis should be required. This service, of course, should comprise roentgenographic and roentgenoscopic interpretation in practically all anatomic and pathologic fields, both general and special. As soon as the student is familiar with the groundwork of diagnosis, he should be invited to make tentative interpretations and give his reasons therefor. The question, 'Why?' often repeated, is an effective spur to straight, clear thinking. Sometimes, I purposely entice the student into making a misinterpretation, in order to arouse a debate that may be more impressive than unquestioned statements. Constantly, the student ought to be stimulated to exercise his reason as well as his memory, to think in terms of morbid anatomy rather than the trite nomenclature of disease, and to draw conclusions either inductively or deductively, but always logically. He should be encouraged to compare roentgenologic diagnoses with the findings at operation and should have opportunities to visit the operating rooms in order to make such comparisons, or to observe or participate in procedures required for ventriculography, salpingography, and roentgenoscopy of the kidney at operation, or other roentgenoscopically controlled interventions. As a further stimulus, some phase of roentgen diagnosis should be assigned to the student for statistical analysis or research, and if the results are noteworthy, they may be given publicity in a joint paper by the student and one of his instructors. Any student who shows an aptitude for research, either in diagnosis or therapy, should have the co-operation of his instructors and should be granted a reasonable amount of time to carry on his investigations in the experimental laboratories of the institution. I feel, however, that student research should not be fostered at the expense of a well rounded training in clinical radiology.

"The nine (9) months' training in therapy should include both roentgen and radium therapy, with thoroughly practical instruction in methods of measuring dosage, technics of treatment, and the selection of technics appropriate for various lesions in various situations. Further, this training should not be confined to methods preferred by the instructor, and the student should be given a fair and impartial insight into methods in vogue elsewhere.

"At institutions where the student is permitted to apply the last six (6) months of his

course as he may elect, events have seemed fully to justify the custom, and almost invariably the period has been well employed.

"Examinations at intervals during the course are desirable to determine whether the student is progressing satisfactorily, and are required by the American Board of Radiology. In some institutions the student is given an alphabetical rating at the end of each quarter by his instructors, and if at any period his rating falls below 'B,' he becomes ineligible for an advanced degree, although such forfeiture does not bar him from continuing his course. Six (6) months after admission, all students in radiology at certain institutions are subjected to examination in the basic sciences of medicine, and the wisdom of applying this test is obvious. Institutions which grant the degree of M.S. in Radiology after the candidate has completed three (3) years of study require him to submit a thesis for approval and pass an examination designed to prove his competence."

There are others, such as Golden (7), who feel that the graduate student should be introduced directly into diagnostic radi-

ology, before taking up the basic sciences. These men think that the needs and applications of the fundamental training will be appreciated more under such circumstances.

The established graduate schools want full and complete understanding of the Council's prescribed courses in order to plan their curriculum accordingly. Due to the absence of any definite program, such institutions have been compelled to place their own interpretation upon the requirements of the Council on Medical Education and Hospitals. To illustrate one temporary program of this nature, we offer the curriculum for graduate instruction in radiology as given at the Graduate School of Medicine of the University of Pennsylvania. As this curriculum is changed from year to year, in the light of additional experience, it must be evaluated only as a serious attempt to meet the specifications of a difficult requirement.

CURRICULUM IN RADIOLOGY, GRADUATE SCHOOL OF MEDICINE UNIVERSITY OF PENNSYLVANIA

Anatomy	Hours	
General anatomy as applied to roentgenography; projection of normal parts on the roentgenogram.	40	O. V. Batson, M.D.
The general anatomy lectures are correlated with roentgen anatomy as follows:		
Normal osseous roentgenologic anatomy.	4	T. A. Henderson, M.D.
Normal cranial roentgenologic anatomy.	4	K. Kornblum, M.D.
Normal thoracic roentgenologic anatomy.	4	F. K. Alexander, M.D.
Normal gastro-intestinal roentgenologic anatomy.	4	J. Gershon-Cohen, M.D.
Normal genito-urinary roentgenologic anatomy.	4	P. A. Bishop, M.D.
<i>Physiology</i>		
Effect of irradiation on normal tissue.	10	E. Lodholz, M.D.
Biological physiology of neoplastic disease.	6	S. P. Reimann, M.D.
<i>Pathology</i>		
General pathology.	30	E. A. Case, M.D.
Morbid anatomy; observation of autopsies and correlation with previous roentgen findings.	20	E. A. Case, M.D.
Pathology of the heart.	9	J. Eiman, M.D.
Pathological physiology of surgical conditions.	45	S. P. Reimann, M.D.
Hematology; the pathological blood picture and its significance.	15	M. M. Strumia, M.D.
Tumor Conference; consideration of current treatment problems as to future therapy.	30	B. P. Widmann, M.D., and staff
Tumor Conference; pathology and treatment of neoplastic disease.	30	E. P. Pendergrass, M.D. P. J. Hodes, M.D.
<i>Physics</i>		
Physics of production and use of roentgen rays in therapy; physics of radium therapy.	32	Mr. J. L. Weatherwax Mr. C. H. Weyl
General consideration of electromagnetic radiation; construction of x-ray apparatus and physics of roentgenography.	30	Mr. R. Warren
<i>Biophysics</i>		
Relation between experimental and clinical radiology.	60	R. E. Zerkel, M.D.

Technic

- Demonstration of x-ray apparatus; position of patient for roentgen examination of various parts; positions for therapy. 26 G. W. Chamberlin, M.D.

Clinical Medicine

- Gastro-enterology; lecture and clinical demonstration. 15 H. L. Bockus, M.D.
- Gastro-enterologic patient presented in conference with gastro-enterologist and surgeon. 30 H. L. Bockus, M.D.
W. E. Lee, M.D.
- Anatomy, diagnosis, surgery, and treatment of neurologic conditions. 30 O. V. Batson, M.D.
F. C. Grant, M.D.
N. W. Winkelman, M.D.
B. J. Alpers, M.D.
W. Drayton, Jr., M.D.
F. H. Leavitt, M.D.
J. C. Yaskin, M.D.
- Syphilology, general and special lectures on diagnosis and treatment. 22 F. D. Weidman, M.D.
S. S. Greenbaum, M.D.
W. H. Mackinney, M.D.
L. C. Peter, M.D.
J. H. Stokes, M.D.
G. M. Piersol, M.D.
C. S. Wright, M.D.
R. L. Gilman, M.D.
J. P. Guequierre, M.D.
D. M. Pillsbury, M.D.
J. C. Yaskin, M.D.
D. Smelzer, M.D.
H. Beerman, M.D.

Roentgen Diagnosis

- Illustrated lectures on the application of roentgenography in the diagnosis of disease. 28 G. E. Pfahler, M.D.
K. Kornblum, M.D.
E. P. Pendergrass, M.D.
R. S. Bromer, M.D.
B. P. Widmann, M.D.
- Conference on roentgen diagnosis; films of interesting cases shown by attending radiologist. 64 E. P. Pendergrass, M.D.
- Demonstration of application of roentgen diagnosis in surgical conditions. 30 K. Kornblum, M.D.
- Conference on roentgen diagnosis. 32 Radiologic Staff of Phila. Gen. Hospital
- Pediatric roentgenography. 22 R. S. Bromer, M.D.
- Roentgen diagnosis of disease and injury of bones and joints. 30 T. A. Henderson, M.D.
- Roentgen diagnosis of arthritis. 4 E. W. Spackman, M.D.
- Roentgenography of disease and injury to the cranial vault and its contents. 20 K. Kornblum, M.D.
- Localization of opaque foreign bodies in the eye. 5 E. W. Spackman, M.D.
- Roentgenologic diagnosis of disease of the paranasal sinuses; roentgenography of the mastoid. 10 E. P. Pendergrass, M.D.
- Roentgen diagnosis of mouth and jaw. 2 P. J. Hodes, M.D.
- Roentgen technic and diagnosis of teeth and jaws. 16 P. A. Bishop, M.D.
- Roentgen diagnosis of disease of urinary tract. 30 L. M. Ennis, M.D.
- Uterosalphingography; technic and interpretation. 2 K. Kornblum, M.D.
- Pelvimetry; history, technic and interpretation. 2 P. A. Bishop, M.D.
- Interpretation of the cardiac silhouette; normal and abnormal. 2 R. P. Barden, M.D.
- Roentgen diagnosis of non-tuberculous infections and neoplastic disease of the lung. 20 H. W. Ostrum, M.D.
- Roentgen diagnosis of pulmonary tuberculosis; demonstration of pneumothorax therapy and indications for its use. 10 F. K. Alexander, M.D.
- Importance of serial films of equal quality in the study of tuberculosis of the lung; relation of non-specific infection of lung bases to healing of tuberculosis of the lung. 17 J. Gershon-Cohen, M.D.
- Roentgenography of esophagus, stomach, and duodenum. 4 M. McPhedran, M.D.
- Roentgenography of gall bladder. 2 K. Kornblum, M.D.
- Roentgenography of intestines, appendix, and rectum. 2 W. C. Hall, M.D.
- Roentgenography of bones. 2 J. Gershon-Cohen, M.D.
- Roentgenography of tendons, muscles, joints, and blood vessels. 2 R. S. Bromer, M.D.
F. K. Alexander, M.D.

Roentgen and Radium Therapy

- These lectures and demonstrations are correlated as nearly as possible with the pathology lectures.
- Application of roentgen and radium irradiation in the treatment of disease; discussion of various special technics; observation of effect of irradiation on tissues. Hours 31 G. E. Pfahler, M.D.

Use of radium and radon in treatment of neoplastic disease; demonstrations of purification and standardization of radon.	32	B. P. Widmann, M.D.
Observation of diagnosis, technic, and dosage of irradiation; progress of lesions; tumor clinic of Phila. Gen. Hospital.	24	B. P. Widmann, M.D.
Therapy of mouth and jaws.	2	G. E. Pfahler, M.D.
Therapy of non-malignant disease of skin.	2	F. D. Weidman, M.D.
Therapy of malignant disease of skin.	2	B. P. Widmann, M.D.
Therapy of infections of skin and subcutaneous tissue.	2	Elwood Downs, M.D.
Therapy of lymphatic glands, spleen, and leukemias.	2	Lowry Allen, M.D.
Therapy of kidney, bladder, and prostatic tumors.	2	G. E. Pfahler, M.D.
Therapy of tumors of testicle and scrotum.	2	J. Gershon-Cohen, M.D.

Clinics in Radiology

University Hospital
Philadelphia General Hospital
Graduate Hospital

E. P. Pendergrass, M.D., and Associates
B. P. Widmann, M.D., and Associates
K. Kornblum, M.D., and Associates

The graduate class in radiology spends 30 days attending clinics at these three hospitals. Their time is divided between diagnosis and therapy.

After the completion of the first year (8 months) in the Graduate School, the student enters upon his course of clinical training in diagnosis and therapy, which, at the University of Pennsylvania, is upon a Fellowship basis. The student is taught the general routine of the department; the handling of patients, clinic, ward, and private; and the use of the general files, including the reports and films. During the first three months, training also covers developing, processing, and technical radiography. *All of the patients must be seen by a doctor, who outlines the desired examination.*

As the Fellow in Radiology becomes more experienced, he is given more responsibility, his duties being divided between clinical and research. The research work is done under the direction of the Professor of Research Surgery, the Professor of Medical Biophysics, and the Professor of Radiology, either individually or jointly. The clinical duties include:

Fluoroscopy.—Examination of patients for chest and abdomen films; gastrointestinal examinations on ward and clinic patients.

Film Interpretation.—Interpretation of ward examinations twice a week; observation of a part or all of the film interpretation by the chief or his associates.

Emergencies.—On call nights and week-

ends to perform and interpret all roentgen examinations, every other week.

Classes.—Several weekly clinico-radiologic conferences, including medical, surgical, pediatric, and obstetrical departments. Weekly tumor conference.

After the completion of one year in diagnostic radiology, the Fellow is assigned to therapy, which includes some of the various types of roentgen and radium therapy and electro-surgical procedures. In the first two months, the Fellow is taught how to operate the different roentgen therapy machines. During this period, he acts as a technician. A certain number of patients are assigned to him for treatment, with responsibility for the mechanical and clinical portions of the patient's roentgen therapy. In addition, he observes how the machines are calibrated and also takes care of the therapy records.

During the time the Fellow acts as a technician, he is expected to do collateral reading. This is supervised in such a manner that only the better articles on roentgen therapy are studied. One-half hour is reserved three days a week for the Fellow to give an abstract of whatever article he has read. At this time, any questionable points are clarified and an effort is made to show the student the practical value of his reading. In such a manner are discussed the leading articles on data concerning filtration, voltage, milliamperage, distance, etc., with which the Fellow must become acquainted.

By observing the plan of treatment

used on his patients, the Fellow gets an insight in the handling of various lesions. He is taught to watch for the different skin reactions as they appear and, in addition, their proper care. Actual discussion of patients is not stressed during the time the Fellow is engrossed in mastering fundamentals. Daily ward rounds and seeing patients in "follow-up" are a part of his duties at this time, however.

Following this period, the Fellow begins to assist in the actual handling of all new ward patients admitted for radiation therapy. He is expected to work up each patient from the clinical standpoint, after which the appropriate treatment is outlined. This phase of the training is, of a necessity, amply supervised. The Fellow is further expected to prepare depth dose measurements, as a part of the permanent record. By this time, he watches every patient being set up for therapy and gradually takes over the responsibility for this procedure in some patients.

As varying types of malignancy or non-malignant conditions are seen, collateral reading, with particular bearing on the treatment of the disease in question, is assigned to the Fellow. These articles are presented in abstract three times a week, as previously described.

From time to time, as patients requiring topical and interstitial radium present themselves, the problem of radium therapy is discussed. Under proper supervision, the Fellow is required to make up many of the radium applicators. In addition, he assists in all electro-surgical procedures performed by the radiologic staff. He is also expected to attend autopsies of radiologic interest.

This outlines, briefly, the type of training given to our Fellows in Radiology. On completion of the Fellowship, those physicians of unusual ability may remain as semi-permanent members of the staff until such time as satisfactory positions elsewhere become available. This obviates the necessity of a good man's

having to accept the first offer that presents itself.

IX. GRADUATE INSTRUCTION FOR THE ESTABLISHED SPECIALIST

Every radiologist must continue to be a student throughout his professional life, if he is to fulfill his obligation of supplying satisfactory medical service in his individual community. At present, there is no comprehensive plan for keeping the radiologist abreast of new contributions to medical science. There are, of course, the meetings of medical societies, medical periodicals, the occasional itinerant course, and post-graduate assemblies. All of the foregoing are absolutely essential, but some other plan must be devised to keep the radiologist who is certified as a specialist acquainted with current proficiencies. To assist in accomplishing this objective, two plans are being considered.

Special Courses at Annual Meetings.—In other branches of medicine, such as ophthalmology and otolaryngology, a "Section on Instruction" has been created as an integral part of the annual meeting of these organizations. The Radiological Society of North America has used this plan for years with considerable success. Their conferences are well attended and popular. The instructors are radiologists and teachers in allied branches and each is an authority on the subject he presents. Sufficient time is allotted for a comprehensive presentation and discussion of a subject. This type of post-graduate training needs further development.

Short Advanced Courses at Selected Institutions.—With only a few exceptions, there are no institutions providing advanced and refreshing courses for the radiological specialist. There is, however, an increasing demand for this type of instruction. The successful short and intensive courses are so organized that the doctor taking them is kept busy the entire day. The instruction is given by the senior members of the staff and is maintained on a high plane.

CONCLUSION

In concluding this paper, which presents in detail the development of undergraduate and graduate instruction in radiology during the past few years, along with a discussion of some of the prevailing methods of instruction, it seems to me that an excerpt from an address by Harold W. Dodds (8), President of Princeton University, is peculiarly fitting:

"Plato's immortal allegory of the men chained in a cave was never more appropriate than to-day. You remember that the unfortunate creatures, representing society in general, are bound in the darkness with their faces to the wall; that there is a fire behind them, and that real figures pass between them and the fire so that the imprisoned men can see the shadows of the figures on the wall, but never the figures themselves in reality. Occasionally a prisoner is freed from his chains and led above to the daylight, where he learns the realities behind the shadows and learns how imperfect were his earlier impressions. Thereafter, it becomes his duty to return to the cave and help disperse the ignorance of his fellows."

Does not this allegory express the opportunity and obligation the radiologist owes to medicine? Is it not our duty, having seen the reality, to train men with the talent, the intellect, and the will to work, so that they, in turn, may be able properly to interpret the shadows in the light of modern physiology and pathology?

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THREE-YEAR RESULTS IN THE TREATMENT OF MALIGNANT NEOPLASMS WITH SUPERVOLTAGE ROENTGEN THERAPY¹

By T. LEUCUTIA, M.D., Department of Radiology, Harper Hospital, *Detroit, Michigan*

SUFFICIENT time has now elapsed since the introduction of supervoltage roentgen therapy so that one may estimate the merit of this technically and physically interesting method also from the clinical standpoint. It is even possible to compile statistical data and by arranging the results according to certain more or less standardized criteria one may draw survival curves which can easily be compared with those obtained with the 200 kv. equivalent² radiation therapy. Such curves acquire special documentary value when they express the continuation of a work in one and the same institution over a long period of time. In Harper Hospital, a total of 312 cases of malignant neoplasms were treated during the years of 1933 and 1934 by supervoltage roentgen therapy, mostly with 500 kv. equivalent (7 mm. Cu forefilter) radiation. These cases were compared, on the basis of survival rates, with those treated with the 200 kv. equivalent radiation prior to those years and survival curves were drawn which in some instances extended as far back as 1922 (15 years). In the present paper, the three-year results obtained with supervoltage roentgen therapy are presented, and in order to bring out the comparative value of the two types of radiation to greater advantage the material is divided into three main groups: (1) cases which proved complete failures to the 200 kv. equivalent radiation and later were subjected to supplemental irradiation with 500 kv. equivalent;

(2) cases which were primarily irradiated with 500 kv. equivalent but in which results or survival curves showed no change from the 200 kv. equivalent radiation therapy; (3) cases which were primarily irradiated with 500 kv. equivalent and in which there was a very definite improvement as compared to the 200 kv. equivalent radiation therapy.

(1) The cases of the first group are shown in Table I.

TABLE I.—DEEP THERAPY FAILURES SECONDARILY TREATED WITH SUPERVOLTAGE THERAPY (1933-1934): STAGES IV-V

Type of Malignancy	Year	Total	Alive
Breast cancer	1933	6	—
	1934	2	1
Gastro-intestinal cancer	1933	5	—
	1934	6	—
Genito-urinary malignancy	1933	—	—
	1934	5	—
Oral cancer	1933	4	1
	1934	3	—
Sarcoma	1933	4	—
	1934	6	—
Uterine cancer	1933	18	1
	1934	17	2
Ovarian malignancy	1933	7	1
	1934	1	—
Various malignancies	1933	2	—
	1934	7	1
Total:	8 per cent	93	7

It is noted that of 93 cases of 200 kv. equivalent roentgen therapy failures which were secondarily irradiated with 500 kv. equivalent, only seven (8 per cent) were alive after three years and in most of these instances the disease was not entirely eradicated. One may add that only such cases were considered as primary failures to the 200 kv. equivalent roentgen therapy in which the dose was carried to the upper-

¹ Presented before the Fifth International Congress of Radiology, in Chicago, Sept. 13-17, 1937.

² The term "equivalent" in specifying the quality of the radiation employed for treatment is used in order to differentiate it from other values as, for example, would be 500 kv. "peak." It appears that irradiation obtained by 500 kv. equivalent corresponds to the quality of the radiation obtained by about 750 kv. peak. Thus without specifying one or the other, one may be apt to misconstrue the results, especially as it concerns the reaction.

most limit of skin tolerance and yet the pathologic lesion continued to show unabated clinical progress. It thus appears that by secondarily subjecting such cases to roentgen therapy with more penetrating rays—in other words, by changing the quality of radiation—a very small or practically no material improvement is obtained as far as the final results are concerned.

(2) In the cases primarily treated by supervoltage roentgen therapy, it was observed that the law of radiosensitivity of the various tumoral tissues remained essentially the same as known for the deep roentgen therapy. Tumors that responded readily to the 200 kv. equivalent radiation were found to respond readily also to the 500 kv. equivalent radiation. On the other hand, such unfavorable groups to the 200 kv. equivalent radiation as malignant neoplasms of the gastro-intestinal tract, with the exclusion of carcinoma of the rectum, or melanosa, etc., continued to show the same unfavorable results also with the 500 kv. equivalent radiation. It appeared in this respect that there was no direct quality dependence with increasing voltages and that, therefore, nothing could be gained by replacing deep roentgen therapy with supervoltage roentgen therapy purely on such a basis, all other factors remaining identical. Perhaps one may mention that the phrase "direct quality dependence" is used in the sense of "selective" action as defined by Russ and Scott, according to which a selective action of an irradiation occurs when a beam in passing through a collection of cells causes some varieties to be more affected than others, quite irrespective of the variation in the intensity of the irradiation as it goes from one point to another or from plane to plane.

In Table II are included the results of some of the unfavorable groups, as well as other more favorable groups but in which the addition of supervoltage roentgen therapy has brought no amelioration worthy of note over the 200 kv. equivalent radiation. The reason for lack of improvement in these latter may be sought either

in the fact that the irradiation situations were little changed, if any, from those of the 200 kv. equivalent radiation, or that the malignant process has already advanced to a stage which was beyond the reach of a permanent cure.

TABLE II.—CASES PRIMARILY TREATED WITH SUPERVOLTAGE THERAPY (1933–1934): UN-INFLUENCED GROUPS

Type of Malignancy	Year	Stage	Total	Alive
Breast cancer	1933	IV-V	5	—
	1934	II	2	2
		III-V	7	—
Gastro-int. cancer, including cancer of rectum	1933	IV-V	9	1
	1934	IV-V	19	2
Genito-urinary malignancy, including cancer of bladder and prostate	1933	IV-V	6	1
	1934	IV-V	15	1
Ovarian malignancy	1933	V	5	—
	1934	V	6	—
Cancer of larynx	1933	IV	2	—
	1934	IV	11	2
Less II Total: 8 per cent			87	9
			2	2
			85	7

(3) Primary supervoltage roentgen therapy with or without association of other methods may be expected to yield better results than the 200 kv. equivalent radiation under two circumstances: first, if the radiation has been rendered more efficacious, and second, if the lesion, or malignant neoplasm, is of such a nature as to remain localized for a longer while. As far as the first circumstance is concerned, it appears quite safe to state now that with increasing voltages there is a better differential action of the radiation. According to Russ and Scott, a "differential" action occurs when different biological effects take place in any particular tissue after exposure to radiation of different wave lengths. The nature of such action is not altogether clear but as experimental evidence accumulates, it becomes more and more obvious that a certain relation to

energy absorption exists. Because of the decreasing photoelectric and increasing Compton effect, on one hand, and because of the greater penetration and more straightforward scattering, on the other, the amount of radiation which is delivered to various tissue depths increases gradually with increasing voltages. Hence one may surmise that better absorption conditions are created which lead to a better differential effect. Since such factors are functions depending on the wave length of the irradiating beam, we may concede that the differential action represents an "indirect quality dependence" at the least. From a practical standpoint this means that a larger total dose may be administered to a certain neoplasm when using higher voltages than is possible with the 200 kv. equivalent radiation and that at the same time there is less injury to the skin. In other words, the irradiation becomes more homogeneous and efficacious.

The second circumstance is the result of the nature of the neoplasm and its stage of clinical development. For the past fifteen years it has been the custom at Harper Hospital to classify all malignant neoplasms, as far as possible, into five stages, according to the degree of demonstrable clinical extension: I, local lesion; II, metastases to the first regional lymph nodes; III, metastases to the second regional lymph nodes through anastomosis with the first; IV, wide local invasion by continuity, and V, distant metastases. When supervoltage roentgen therapy was first introduced in 1933 and during the following year of 1934, it was applied chiefly to cases of Stages III and IV. The cases in Stages I and II are considered operable and, therefore, in these groups the old established methods of treatment were pursued either by employing an association of surgery and irradiation or by irradiation alone with a technic as formerly practised. Stage V, on the other hand, represents such extensive dissemination of the malignant process that the possibility of a cure is practically eliminated, whereas palliation may be brought

about by other less expensive methods. It was our impression from the beginning that the greatest improvement by the supervoltage roentgen therapy may be produced in Stage IV in those types of tumors which remain of local character for a long while, although the invasion by continuity may be a very considerable one. To use a few illustrations, a carcinoma of the breast is placed in Stage IV when there is invasion with adherence of the anterior thoracic wall, a carcinoma of the cervix when there is a completely frozen pelvis, even associated with communicating recto- or vesicovaginal fistulae, a carcinoma of the larynx when there is extrinsic invasion of the structures of the neck, a carcinoma of the skin when there is invasion of the underlying bone, a carcinoma of the rectum when there is extension into the perirectal structures, etc.

By radiating such situations with 500 kv. equivalent roentgen rays, indeed, at times very surprising results were obtained. The best example is represented by the carcinoma of the uterine cervix. Figure 1 shows the survival curves in our material for three, five, and ten years in a total of 531 cases treated since 1922. There hardly can be any doubt that the three-year survival curve has undergone a very remarkable rise since the introduction of the supervoltage roentgen therapy, the percentage increasing from 30 to nearly 60. Perhaps one should mention that the curves up to 1933 included all cases examined, whether properly or improperly treated, and thus represent absolute values, whereas the three-year curve since 1933 includes only those cases which received proper irradiation with supervoltage roentgen therapy (and intracavitary radium) and thus represent relative values. But even so, the improvement cannot be denied. In many instances, advanced cases with communicating fistulae have led to complete healing, there being no evidence of carcinoma whatsoever three years later. It appears thus that carcinoma of the uterine cervix remains localized to the pelvic structures for a relatively long while,

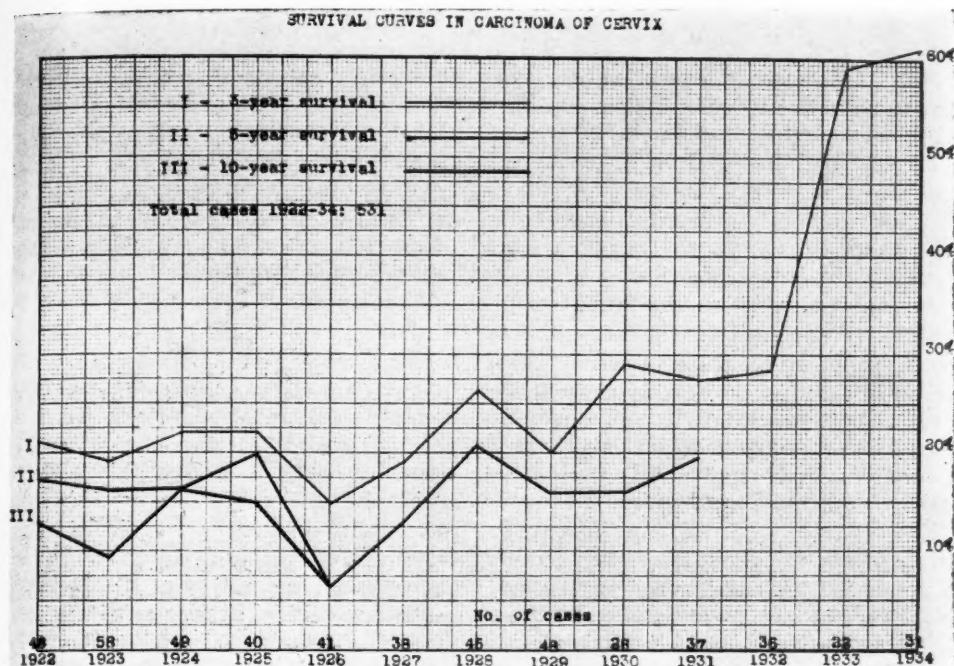


Fig. 1.

fatal complications arising nearly always through effect on the neighboring organs, and that the more efficacious irradiation with the supervoltage roentgen therapy (and radium) can lead to cure in the most advanced cases, there being no, or very little, danger of distant metastases.

A similar situation exists in certain bulky skin cancers with invasion of the underlying bone, in carcinoma of the rectum and the earlier cases of carcinoma of the prostate, in some types of sarcoma, in carcinoma of the thyroid and to a lesser extent in metastatic carcinoma to the lymph nodes of the neck (either from oral or mammary primary). In a total of 122 such cases of Stages III, IV, and V, the three-year survival was 40 per cent. The results in these cases are shown in Table III.

SUMMARY AND CONCLUSIONS

A total of 312 cases of malignant neoplasms were treated during 1933 and 1934 at Harper Hospital by supervoltage roent-

gen therapy, mostly with 500 kv. equivalent (7 mm. Cu prefilter) radiation. The following conclusions may be drawn from

TABLE III.—CASES PRIMARILY TREATED WITH SUPERVOLTAGE THERAPY (1933-1934): IMPROVED GROUPS

Type of Malignancy	Year	Stage	Total	Alive
Skin cancer (bulky)	1933	IV	1	—
	1934	IV	6	3
Cancer of thyroid	1933	IV-V	2	1
	1934	III-V	3	2
Cancer of bronchus	1933	I-V	8	1
	1934	I-V	5	2
Oral cancer with metastasis to glands of neck	1933	III-V	12	2
	1934	I	3	3
		III-V	11	1
Sarcoma	1933		7	1
	1934		17	7
Uterine cancer	1933	A-II	2	2
	1934	IV-V	21	12
		A-I-II	5	5
		IV-V	29	17
Total			132	59
Less I-II			10	10
Total: 40 per cent			122	49

a study of the survival curves in these cases:

(1) If a thorough irradiation with 200 kv. equivalent has led to failure in a certain instance, the supplemental irradiation with 500 kv. produced no material improvement in the final results.

(2) In the cases primarily treated with supervoltage roentgen therapy no change in the law of radiosensitivity was observed as compared to the 200 kv. radiation. It appeared in this respect that there is no direct quality dependence or selective reaction. The groups of malignant tumors which proved unfavorable to the 200 kv. equivalent irradiation continued to remain unfavorable also to the 500 kv. equivalent irradiation.

3 Primary supervoltage roentgen therapy with or without association of other methods led to better results in all those instances in which the irradiation has been rendered more efficacious, as compared to the 200 kv. equivalent radiation, but in

which the malignant process was still of local character although the invasion by continuity appeared very considerable. The increased efficacy may be attributed to better absorption conditions, signifying an indirect quality dependence or differential action. If all malignant neoplasms are divided into five clinical stages, it is found that supervoltage roentgen therapy has led to definite improvement of the three-year results in Stages III and IV, in those groups which were favorable also to the 200 kv. equivalent radiation. The best example is represented by the carcinoma of the uterine cervix in which the percentage of three-year survival was increased from 30 to nearly 60. A similar improvement was obtained in certain bulky skin cancers, in carcinoma of the rectum, in the earlier cases of carcinoma of the prostate, in some types of sarcoma, in carcinoma of the thyroid, and to a lesser extent in metastatic carcinoma of the lymph nodes of the neck.

ANOMALIES OF THE LUMBO-SACRAL SPINE¹

By PAUL C. WILLIAMS, M.D., Dallas, Texas

It has long been the opinion of those who have had occasion to deal with orthopedic problems that an anomalous lumbo-sacral spine is capable of producing pain. The exact cause of symptoms in those patients presenting such a lesion has been and yet remains a subject of controversy.

Schmorl from his extensive postmortem studies did not venture far into the clinical aspect but apparently was of the opinion that clinical symptoms in such cases were due to secondary degenerative changes.

The bizarre clinical findings presented by these patients are going to require the best combined efforts of the radiologist, neurologist, and the orthopedist before a satisfactory explanation can be made and a rational form of treatment established. It is probable that when all secondary pathologic changes are understood it will be unnecessary to resort to vague terms in explaining pain distributions.

When one realizes that there are at least 18 different muscles in each lower extremity which receive part of their innervation from the fifth lumbar segment, it is not difficult to understand the widespread distribution of pain presented by a patient suffering with a lesion of this segment. Sensory distributions are also confusing. This has been demonstrated by the classical work of Foerster who has shown a wide individual variation in distributions and extensive overlapping of the dermatomes of the lower extremities. In those cases presenting an extra vertebra there is undoubtedly an extra nerve segment which adds further to the confusion of the neural examination.

It has been found by the author from a study of 1,000 patients who complained of pain in the lower part of the back and

legs that the x-ray studies of approximately 30 per cent showed an anomaly of the lumbo-sacral spine. About 16 per cent presented the anomalies commonly spoken of as lumbarization and sacralization. While this terminology will be employed in this paper it is not wholly adaptable due to the fact that an occasional case actually presents an extra-vertebral segment within the column. For this reason, unless studies of the entire spine are available, it is well to use the terminology of Schmorl who has spoken of these segments as lumbo-sacral transitional vertebrae.

Since x-ray studies of the entire column were not available in all cases in this series it has been necessary to classify according to the number of sacral segments presented. Thus the term "lumbarization" indicates that there are four sacral vertebrae below the anomalous segment, while "sacralization" indicates that there are five sacral vertebrae below the anomalous segment.

The accompanying classification with the percentage of occurrence of each lesion includes only those anomalies which in the author's opinion are responsible for clinical symptoms.

Lesion	Percentage Occurrence
1. Sacralization	7.00
2. Lumbarization	8.75
3. Imperfect fusion of sacral lateral masses	7.75
4. Spondylolisthesis	3.25
5. Facet fragmentation and anomalies	2.00
Total	28.75

The majority of patients suffering with anomalous lumbo-sacral spines present both localized and segmental symptoms. When a nerve root approximates a degenerative bone change so closely that it becomes irritated, either by an inflammatory reaction or direct mechanical contact, segmental symptoms result. There are de-

¹ Presented before the Fifth International Congress of Radiology in Chicago, Sept. 13-17, 1937.

generative changes in many of these cases which are capable of producing only localized symptoms due to the fact that they are separated too far from the nerve roots. One example of this is the sclerosis and spur formation so frequently seen in the anomalous spine involving the inferior margins of the sacro-iliac joint. Another example is the degenerative change involving the joint formed by the anomalous transverse process of the fifth lumbar vertebra and the lateral mass of the first sacral vertebra. To ascribe to such changes anything more than localized pain and protective spasm is not in keeping with the anatomy of the part.

The primary purpose of this paper is to deal with those changes which are responsible for segmental pain which radiates into the extremities. Less severe nerve symptoms which will not be discussed but which should be mentioned are those which accompany the twelfth dorsal and upper lumbar segments. Such cases usually present a pelvic obliquity and a primary

lumbar curve. The symptoms appear as a hyperesthetic zone corresponding to the dermatome of one or more of the segments mentioned. The change is most frequently found on the side which corresponds to the concavity of the curve and is probably due to the reaction caused by the abnormal stress thrown on the facets of the concave side. Similar nerve changes are frequently found in cases of scoliosis due to other causes.

The intervertebral disk which joins an anomalous vertebra with the segment below is usually thin and rudimentary in character. It is unlikely that the prolapse of such a disk or its nucleus into the neural canal would play any part in the production of segmental symptoms; however, this question remains to be proven.

SACRALIZATION

Sacralization of the fifth lumbar vertebra was found in 7 per cent of the cases. Its occurrence was more frequent in the female than in the male. The fixation may

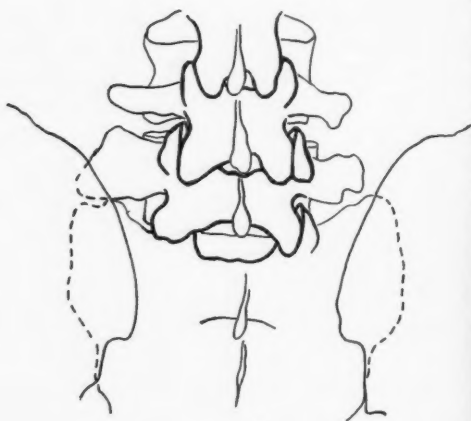


Fig. 1. Unilateral sacralization showing subluxation of the articular facets between the fourth and fifth lumbar vertebrae and the lumbo-sacral facets on the free side.

be either unilateral or bilateral. Segmental symptoms resulting from such a lesion are not due to the anomaly itself, but

bræ (Fig. 1). There is also a narrowing of the posterior portion of the fourth lumbar intervertebral disk which may be but slight



Fig. 2. Unilateral sacralization showing settling of the disk on the free side.

rather are caused by degenerative changes resulting from altered mechanics which have caused an abnormal stress on the intervertebral disk.

Symptoms resulting from a unilateral sacralization may appear in young adult life or may be delayed until middle life. When appearing in young adult life there is usually a history of injury. In addition to the localized symptoms these patients frequently complain of pain in the lower anterior thigh and knee on one or both sides. A history of the knee "giving way" is not uncommon. Segmental symptoms follow primarily the distribution of the fourth lumbar nerve.

Careful x-rays of such a case will reveal a subluxation of the articular facets between the fourth and fifth lumbar verte-

at this stage. The vertex of the lumbo-sacral angle is located between the fourth and fifth lumbar vertebrae rather than between the fifth lumbar and first sacral vertebrae. This indicates abnormal stress on the posterior fibers of the fourth lumbar intervertebral disk.

Providing the fourth lumbar intervertebral disk escapes acute traumatic changes, patients do not develop symptoms until they approach middle life. The usual course of events is a gradual onset of pain in the lower back, followed in a period of weeks, months, or years by pain radiating down the leg opposite the fixed transverse process to the posterior thigh and lateral aspect of the calf, ankle, and foot. Symptoms and findings follow the distribution of the fifth lumbar nerve.

The x-rays reveal a narrowing of the fifth lumbar intervertebral disk and a subluxation of the lumbo-sacral facets on the side opposite the fixed transverse process (Fig. 2). If the history of pain dates from young adult life there will also be observed a narrowing of the fourth lumbar intervertebral disk and a subluxation of the facets between the fourth and fifth lumbar vertebrae as shown in Figure 1.

Bilateral sacralization of the fifth lumbar vertebra, providing there is bony or good fibrous fixation, is an excellent assurance against degenerative changes of the lumbo-sacral articulation. When symptoms from such a lesion appear early in life there is usually a definite history of injury. When they appear in middle life the onset as a rule is insidious in character. Segmental symptoms accompanying this lesion follow primarily the distribution of the fourth lumbar nerve on either side.

The x-rays reveal a narrowing of the fourth lumbar intervertebral disk and a

subluxation of the corresponding facets. The degree depends on the duration of the lesion (Fig. 3).

LUMBARIZATION

Lumbarization of the first sacral vertebra was found in 8.75 per cent of the cases in this series. Its occurrence was slightly more frequent in the male than in the female. Like the former lesion, it may be either unilateral or bilateral, and clinical symptoms are due to traumatic degenerative changes caused by altered mechanics.

Unilateral lumbarization may cause segmental symptoms, in addition to localized pain, as a result of traumatic degenerative changes at two different sites. Patients presenting this anomaly and who suffer symptoms during young adult life usually give a history of injury. If the pain radiates down the extremity, it follows primarily the distribution of the fifth lumbar nerve. Either extremity may be involved.

The x-rays on such a patient will reveal

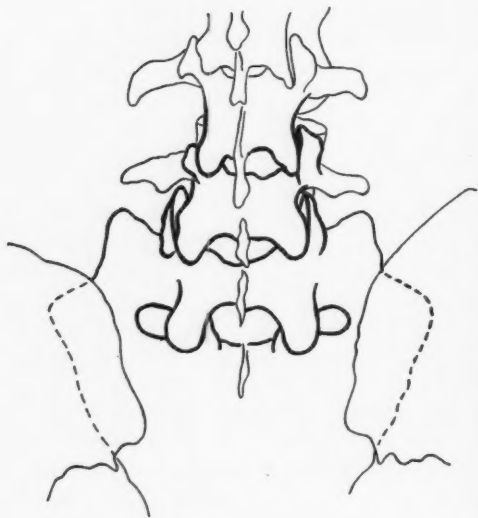


Fig. 3. Bilateral sacralization showing subluxation of the articular facets between the fourth and fifth lumbar vertebrae.

a subluxation of the lumbo-sacral facets and a narrowing of the lumbo-sacral intervertebral disk (Fig. 4).

Patients presenting the same anomaly may not develop symptoms until middle or late life. Segmental symptoms following the course of the fifth lumbar nerve may be present on either side, but frequently there is also clinical evidence of first sacral nerve involvement on the side which corresponds to the lumbarized lateral sacral mass.

The x-rays on such a case in addition to the narrowing of the lumbo-sacral intervertebral disk and the subluxation of the lumbo-sacral facets show a narrowing of the rudimentary disk and a subluxation of the imperfectly developed facets between the first and second sacral vertebræ on the free side (Fig. 5). The degenerative changes are usually quite apparent at this age period.

Bilateral lumbarization of the first sacral vertebra may or may not cause clinical symptoms, depending to a large extent on

the amount of mobility between the first and second sacral vertebræ.

The distribution of pain in those presenting this anomaly varies considerably with the age of the patient. If clinical symptoms appear between the ages of 20 and 45 and progress to the point at which pain is radiating down the lower extremities, it will be found that such symptoms follow primarily the distribution of the fifth lumbar nerve. Either extremity may be involved. Symptoms in these patients cannot be differentiated clinically from those whose x-rays show a destruction of the lumbo-sacral intervertebral disk without an anomalous spine.

The x-rays aside from the anomaly show a narrowing of the lumbo-sacral intervertebral disk and a subluxation of the corresponding facets. The degree as viewed in the roentgenogram varies directly with the duration of the destructive process.

After the age of 45, with or without the symptoms already described in the younger group, these patients may present segmen-

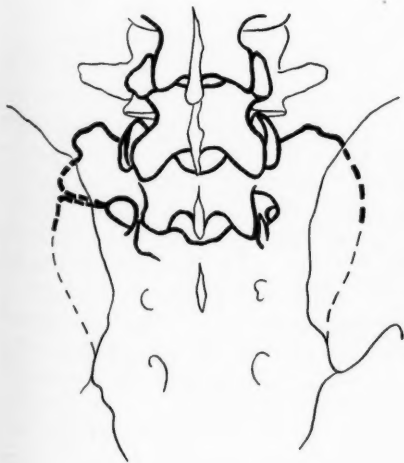


Fig. 4. Unilateral lumbarization showing subluxation of the lumbo-sacral facets.

tal symptoms throughout the distribution of the first sacral nerve on either side.

The x-rays on such a case show degenera-

Segmental symptoms predominate in this lesion and follow the distribution of the fifth lumbar, first, second, and third sacral



Fig. 5. Unilateral lumbarization showing narrowed rudimentary intervertebral disk and subluxation of facets on free side (retouched).

tive arthritic changes involving the rudimentary facets between the first and second sacral vertebrae in addition to the lumbosacral changes. Due to superimposed bony structures this is one of the most difficult cases to reveal by the x-ray, and for this reason a most careful technic must be employed (Fig. 6).

IMPERFECT FUSION OF SACRAL LATERAL MASSES

Imperfect fusion of the sacral lateral masses was found in 7.75 per cent of the cases in this series. Its occurrence was found to be practically the same in the two sexes. In the majority of cases symptoms make their appearance in young adult life. There is usually a history of injury which may be comparatively mild in character

nerves. Pain through the third sacral nerve radiating into the scrotum in the male and the labia in the female invariably suggests pathologic changes of the genitourinary tract. For this reason these patients are investigated time and again for such changes.

It is possible that a prolapse of the nucleus pulposus of the fifth lumbar intervertebral disk is responsible for sacral nerve symptoms in this lesion. Again they may be due to irritation of the sacral nerves within the narrow sacral neural canal caused by motion between the first and second sacral vertebrae. The latter view has been strengthened by a case operated upon which revealed adhesions of the sacral nerves at this site. The fifth lumbar nerve changes which predominate after symptoms have

become chronic must be explained on the basis of facet changes due to the fact that this nerve emerges from the canal without crossing the lumbo-sacral disk.

From the x-ray study this lesion might well be considered the mildest form of a lumbarized first sacral segment. The lateral masses of the first and second sacral segments show an imperfect or complete failure of fusion. The sacrum forms a double articulation with the ilium, and traumatic degenerative changes involving the inferior borders of the sacro-iliac joint are evidenced by sclerosis and osteophyte formation at this site. Such changes may be observed as early as the latter half of the second decade of life. The lateral studies show a rudimentary intervertebral disk between the first and second sacral vertebrae. In most cases presenting this lesion there is a degeneration of the lumbo-sacral intervertebral disk and a subluxation of its corresponding facets (Fig. 8).

SPONDYLOLISTHESIS

Spondylolisthesis was found in 3.75 per cent of the cases in this series. Its occurrence was practically the same in both sexes.

This lesion may cause symptoms at any age period after infancy. The clinical findings vary widely with individuals, depending to a large extent on the amount of forward displacement. Segmental pain is not a predominant finding in these cases; pain in the lower part of the back radiating through to the abdomen, the anterior upper thigh, and the groin is a more common finding. Symptoms of this lesion may be mistaken for appendicitis or a pelvic disorder.

The x-rays show a bilateral break in the bony continuity of the pedicle of the fifth lumbar vertebra and in most cases a varying degree of forward displacement of the lumbar spine on the first sacral table (Fig. 7). In rare cases the forward displacement may progress to the extent that the lumbar spine descends in front of the sacrum. Occasionally a similar lesion involving the fourth lumbar vertebra may be observed.

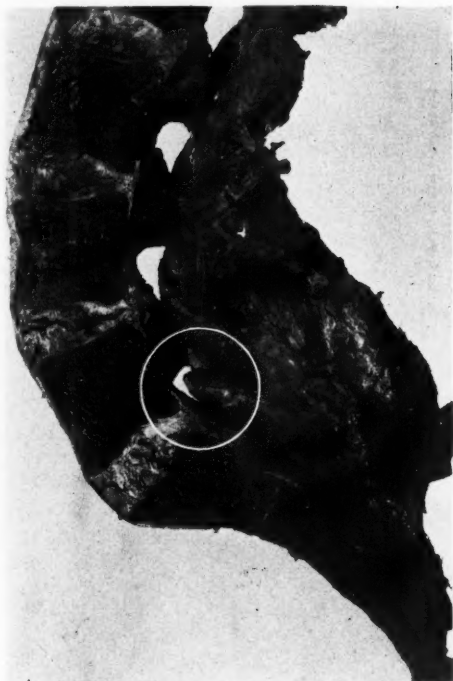


Fig. 6. Lumbarization of first sacral vertebra showing degenerative arthritic changes of rudimentary superior second sacral facet.

FACET FRAGMENTATION AND ANOMALIES

Facet fragmentation and anomalies were found in 2 per cent of the cases in this series.

There is always considerable question whether a break in the bony continuity of a facet is the result of trauma or altered development. Mitchell has considered such lesions as fractures, while Nichols and Shiflett have referred to them as ununited anomalous epiphyses. The author favors the opinion of Mensor who believes that the majority of such lesions are fractures but that a developmental failure of fusion accounts for the lesser percentage.

The clinical findings are localized pain with its accompanying changes and frequently segmental symptoms involving the distribution of the nerve which emerges at the site of change. A loss of both motor and sensory function of the fifth lumbar nerve on the affected side was observed by the author in such a case. The history,



Fig. 7. Spondylolisthesis showing break in pedicle of fifth lumbar vertebra and forward displacement of lumbar spine on first sacral table.

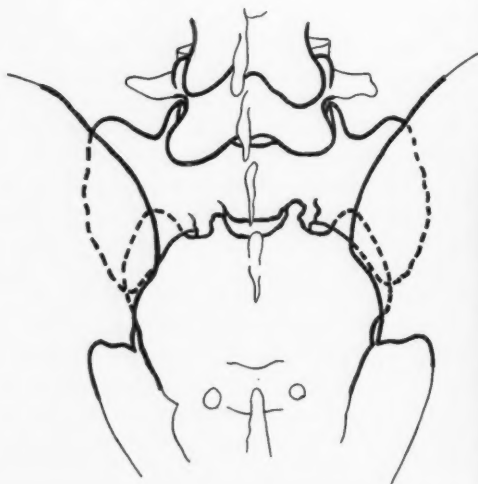


Fig. 8. Imperfect fusion of sacral lateral masses. Patient aged 15 years. Note degenerative arthritic changes involving inferior margin of sacro-iliac joints, double articulation of sacrum with ilium, and subluxation of lumbo-sacral facets.

x-ray, and gross findings suggested a fracture. Complete recovery followed surgical treatment.

Under this phase of the classification there have been included a few rare cases that presented symptoms characteristic of this group and whose x-ray studies showed an over-development of one of the first sacral facets. Aside from the magnitude of the facet there was evidence of sclerosis and marginal irregularity characteristic of a degenerative arthritic change.

Of the few cases seen, symptoms made their first appearance during the fourth decade of life, and clinical examinations revealed that segmental symptoms followed the distribution of the fifth lumbar nerve on the side which corresponded to that of the enlarged facet.

There are other anomalies of the lumbo-sacral spine which have not been included in this classification due to the fact that they play a secondary part in the production of symptoms. A spina bifida occulta of the first sacral vertebra is an example of such a lesion. This lesion in itself has no clinical significance, but when combined



with a destruction of the lumbo-sacral disk it plays a definite rôle. When there is a well formed spinous process of the first sacral segment the descent of the fifth lumbar vertebra and the overriding of the lumbo-sacral facets are stopped by the contact of the spinous processes of the two vertebrae. In the absence of a well formed first sacral spinous process the descent may continue until the first sacral facets lodge in the inferior vertebral notch. The latter results in sclerosis and occasionally spur formation at this site. This is due to the fact that the first sacral facets have been converted into weight-bearing structures. This change can be observed in anteroposterior stereoscopic studies and occasionally is misinterpreted as a break in the bony continuity. Such spurs attached to the inferior vertebral notch of the fifth lumbar vertebra have been observed by the author in three postmortem studies (Fig. 9).

Positional asymmetry of the first sacral facets is a common anomaly of the lumbo-sacral spine. The articular surface of one facet may be in the anteroposterior plane while that of the other may be in the transverse or oblique plane. The mechanical disadvantage resulting from such a variation undoubtedly hastens a degenerative change of the facet articulations. In the author's opinion, however, such an anomaly in itself is not productive of significant clinical symptoms. When observed in the x-ray film of a patient suffering symptoms characteristic of this group there are usually associated a settling of the lumbo-sacral intervertebral disk and an overriding of the facets.

It is not the purpose of this paper to discuss treatment; however, in planning such the importance of carefully posed and thoroughly studied x-ray films cannot be over-emphasized. The same is true of the clinical examination and observation. A hasty decision to fuse the anomalous lumbo-sacral spine frequently results in an unjust criticism of the procedure. Treatment both surgical and non-surgical should be directed at widening the constricted foramina and putting to rest joints which

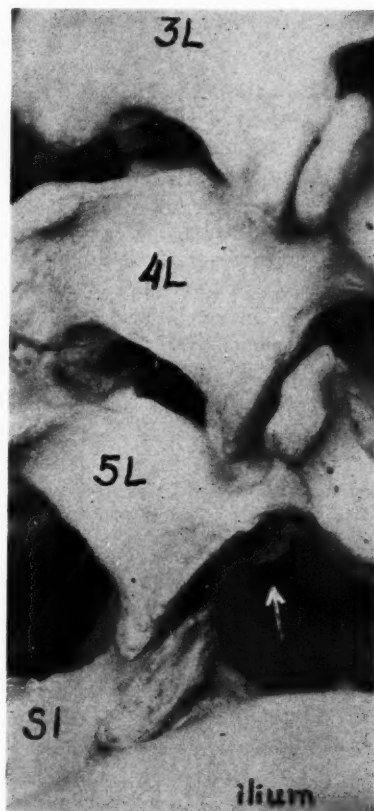


Fig. 9. The descent of the fifth lumbar vertebra is occasionally stopped by the first sacral facet which lodges in the inferior vertebral notch. This, in turn, causes scarring and spur formation at this site.

have undergone a degenerative change. The former is as important as the latter in the author's opinion.

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A STUDY OF THE EFFECT OF THORIUM DIOXIDE SOL INJECTED IN RABBITS

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THE large number of recent contributions to the literature suggesting the use of radio-active substances as a diagnostic method—such as hepatolienography, arteriography—and as a therapeutic measure, has prompted the present investigation. Following the unpublished work of C. R. Orr and B. R. Stephenson, of our laboratories, who, in 1932, were successful in producing shadowgrams with a section of liver from a patient injected with thorium dioxide sol, we set about determining the latent effects of this radio-active material. Two methods of approach were used: (1) experimental animals were injected with the sol and detailed microscopic examinations made of the reticulo-endothelial structure after

periods of from 24 hours to 385 days; and (2) roentgen films were exposed to prepared ampules of the sol, to dried specimens of the liver and spleen, and to histological sections in an effort to demonstrate radio-activity. We wish to add our findings to those of the increasing group of workers who believe that the use of radio-active salts, particularly the thorium preparations, is fraught with grave danger.

RADIO-ACTIVITY

Thorium is a well-known radio-active element which disintegrates slowly (22), taking several years to reach equilibrium with its disintegration products (Fig. 1). When thorium preparations are first made

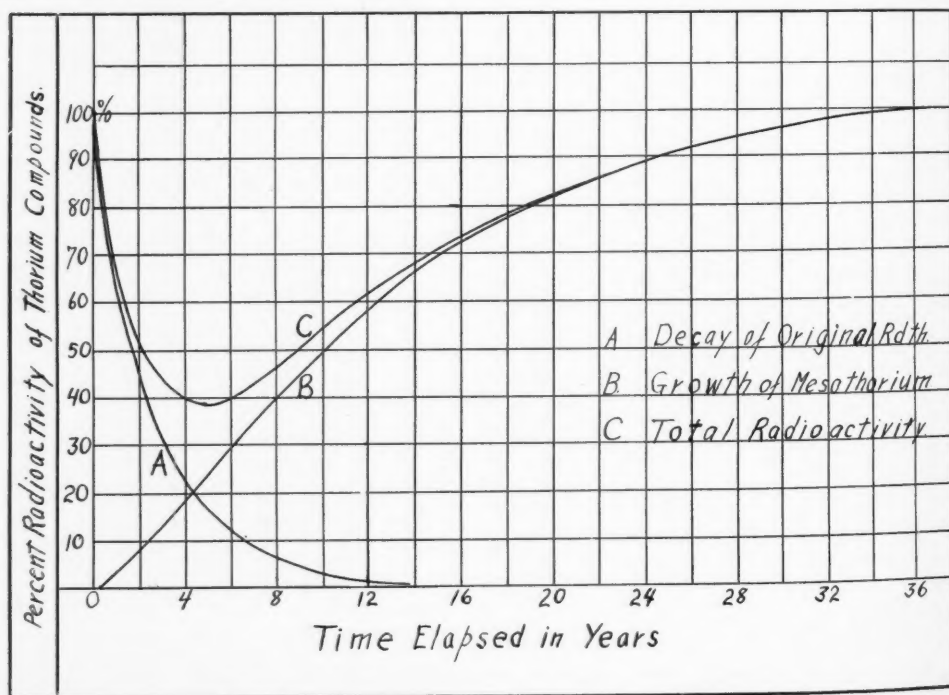


Fig. 1.
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they are free of these products, with the exception of radiothorium. It will be observed in Figure 1 that the original radiothorium has practically disappeared at the end of 12 years and that the total radio-activity is at a minimum at the end of five years. From this point on the activity again increases, attaining a value of 54 per cent of the maximum in ten years and of nearly 90 per cent at the end of 25 years.

Applying the above known facts concerning thorium to the thorium dioxide sol, Schlund (22) found by measurement that one ampule of the freshly prepared sol radiates as many alpha particles per second as one microgram of radium; thus the alpha-ray activity of three ampules (the average human dose) is equivalent to three micrograms of radium. He stated, however, that if the sol is prepared from thorium nitrate which has aged five years, when the activity is at a minimum, it will contain only half this amount, or the equivalent of 1.5 micrograms of radium.

Taft (72, 73) reported a method of determining the radio-activity of a dose of thorium dioxide sol in the patient's body and found it to give off gamma rays equivalent to 1.37 microgram of radium. "Small as this may seem," he states, "it is the amount found in the bodies of the girls who died of radium poisoning contracted when they painted radium on watch dials, and those who use it are on dangerous ground."

The Radium Institute of the Academy of Freiburg, according to Kadrnka (46), investigated the activity of 100 c.c. of thorium dioxide sol and found it to have a radio-activity equivalent to 1.24 microgram of radium.

Warren and his co-workers (69, 70) found that "75 c.c. of thorium dioxide sol is equivalent to 0.8 microgram of radium, while the alpha-ray activity is equal to 1.5 to 3 micrograms of radium. The latter is very important because of the intimate relation between the thorium and the tissue cells in the body."

Evans (77) on Nov. 2, 1936, carried out for us an analysis on a 25 c.c. commercially prepared sample of thorium dioxide sol and found it had a "gamma-ray activity equivalent to 0.25 microgram of radium when both the sol and radium gamma-ray measurements are made with 10 mm. of lead filtration." He believed also that the "alpha-ray effects produced in patients over a period of from five to ten years may be more serious than early gamma-ray measurements might indicate."

REVIEW OF THE LITERATURE

Following the work of Oka (1) and Radt (2, 3), many investigators have carried out more or less extensive experiments on animals, while hundreds of patients have been injected with the thorium dioxide sol for diagnostic purposes. The bibliography of 79 papers here assembled is still only a partial list of all those published on this subject. In reading this literature one becomes aware of the tendency to emphasize the tremendous benefits achieved by the use of the sol as an ideal contrast medium and to minimize its ill effects, particularly those of delayed radio-activity. There are relatively few articles which state that the use of the preparation is definitely dangerous, and should not be used, therefore, in human beings.

The first 36 articles listed in the bibliography all favor the use of thorium dioxide sol, and make very little mention of any possible danger. Many of these articles, it is true, refer to its use in arteriography in which case the dose is relatively small.

Yater and Otell (13), who are widely quoted regarding the harmlessness of thorium dioxide sol, stated that the Bureau of Standards "showed that the radio-activity of thorium dioxide sol is negligible." This was unfortunate, for the Bureau later stated (37) that their earlier tests were informal and that they had not studied this problem sufficiently to make any definite statement.

Another group of writers suggested that

there might be some latent effects from the use of thorium preparations. Ericksen and Rigler (38), while admitting that there might be some possible harm due to long storage, yet believed that thorium is eliminated sufficiently to be used in safety. Robins and Goldberg (39) and Allen and Camp (40) also admitted the possibility of future damage but could find no definite indications of harmful effects. Huguenin and Nemours (41) suggested it might cause some hepatic insufficiency. Ucke (42) believed that blockage by thorium sol might impair the immunizing processes of the endothelial system, while Bauke and Koch (43) and Bucky and Leitner (44) showed by experiments that the phagocytosing ability is measurably decreased in injected rabbits. Ehrhardt (45) found that injected mice did not become pregnant, while Kadrnka (46), on the contrary, found that guinea pigs heavily injected bore normally developed living young. Menville and Ané (47) and Naegeli and Lauche (48) suggest waiting for further study. Rigler, Koucky, and Abraham (49), Kadrnka (46), Cooke (50), Pohle and Ritchie (51), Contiades, Naulleau, and Unger (52), and Capocaccia and Vallebona (53) recommend that, because of the possible damage to the reticulo-endothelial system due to delayed reaction, the use of thorium dioxide sol be limited to aged patients and hopeless cases. Hirsh and Morton (54) placed sections of liver and spleen over films, but were unable to find any trace of radio-activity up to four weeks' exposure; in spite of this they advised the restriction of its use to old persons, or to hopeless cases. Lewisohn (55), Lambin (56, 57), Whitaker, Davie, and Murgatroyd (58), and Vajano (59) all mention the slow elimination of the thorium dioxide sol with its possible delayed results, while Popper and Klein (60) because of the delayed activity, do not accept this method for routine work.

Of those who have opposed the use of radio-active material for injection into the

body, Martland (61, 79) was the first to point out that even very small doses retained in the body over a period of years may cause serious damage. Stewart, Einhorn, and Illick (62) were the first to obtain shadowgrams by placing the spleen from an autopsied case over a photographic plate. They declared that, in view of the possible danger, the injection of thorium does not give enough independent information to justify its use. Büngeler and Krautwig (63), after a critical analysis, warned that the substance should not be used in human beings, but should remain limited to animal experiments. Büchner (64), Anders and Leitner (65), Leitner (66), and Shute and Davis (67), after careful histological studies, cautioned against its use in human subjects. The Council of Pharmacy and Chemistry of the American Medical Association (68), in 1932, voted that thorium dioxide sol be not accepted for intravenous administration. Pearse (69), in discussing the work of Warren and Oehlbeck (70), stated that the autopsied liver and spleen of animals injected one year previously fogged a film after several days' exposure. In the latter part of 1936 several authors opposed the use of this preparation for injections. Fleming and Chase (71) were the first to obtain shadowgrams of histological sections from an autopsy liver specimen. They advised against the use of thorium dioxide sol in patients if the expectancy of life is more than two years. Taft (72, 73) measured the radio-activity of the product and warned against its use, inasmuch as the radio-activity was equivalent to that which Martland had found to be dangerous. Selbie (74) and Roussy, Oberling, and Guérin (75) also counselled against its use, since they found that it produced sarcomas in experimental rats and mice. Evans (76, 77), after measuring the activity of thorium dioxide sol, stated that the increasing alpha-ray activity of the mesothorium formed would probably prove dangerous to the patient after several years. Finally, the French committee composed of Duval,

TABLE I.—DATA ON RABBITS INJECTED WITH THORIUM DIOXIDE SOL

Rabbit Number	Weight (gm.)	Wt. at Death (gm.)	Date Inj.	Amount Injected		Place Administered	Manner of Death	Time after Inj.	Wt. of Spleen (gm.)	Vol. of Spleen (c.c.)	Wt. of Liver (gm.)	Vol. of Liver (c.c.)
				Total (c.c.)	c.c. per kg.							
12	2,200		12/4/34	2.5	1.1	Intravenous	Killed	24 hours	1.2	1.1		
11	2,200			0	0	0	Killed	24 hours	0.793	0.9		
16	1,900	1,585	12/4/34	2.25	1.2	Intravenous	Nat.	33 mos.	0.533		40	
15	1,900			0	0	0	Nat.	4 mos.				
3	3,600	2,700	6/12/34	16	4.4	Intravenous	Nat.	4.5 mos.				
14	2,640	2,500	12/4/34	12	4.4	Intravenous	Nat.	3 mos.	3.678	2.7	96	91
13	2,640	2,950		0	0	0	Killed	3 mos.	1.58	1.5	87	82
6			7/7/34	20		Intraperitoneally	Nat.	14, 6 mos.				
9			8/22/34	8		"		1 year				
5	2,270		7/20/34	20	8.8	Intraintestinally						

Regaud, Rouhier, Bazy, and B  cl  re (78) recommended that radio-active substances be completely abandoned in therapeutic injections.

EXPERIMENTAL DATA

The purpose of the investigation with thorium dioxide sol was to determine: (1) The site of storage; (2) The delayed effect on body tissue; (3) The degree of radio-activity; (4) The rate of elimination; (5) The route of elimination.

Three groups of rabbits, varying from 2 to 4 kgm. in weight, were injected. The usual method was to inject three equal fractional doses on succeeding days. Rabbits No. 12 and No. 16 received intravenously a total dose of 1.1 and 1.2 c.c. per kgm. body weight, respectively; the controls, No. 11 and No. 15, received none. The second group, No. 3 and No. 14, received intravenously 4.4 c.c. per kgm. body weight; rabbit No. 13 was the control. The third group, No. 6 and No. 9, received intraperitoneally 20 c.c. and 8 c.c., respectively. Rabbit No. 5 received by accident 20 c.c. intra-intestinally. Table I contains a complete summary of the doses, weights, and other pertinent data.

The animals were maintained on the same diet throughout the entire experiment. Roentgenograms were then taken at intervals, employing a constant technic of 56 kv., 100 ma., 30 in. distance, $\frac{1}{120}$ sec. exposure.

RADIOLOGICAL FINDINGS

The roentgenograms of rabbit No. 16 (Fig. 2-C) taken two and one-half years after injection, showed no change in the density of the liver and spleen as compared with roentgenograms taken immediately after injection. Roentgenograms of the humerus of No. 14 (Fig. 2-E), taken three months following injection, showed a marked increase in density of the medullary canal as compared with roentgenograms of the control No. 13 (Fig. 2-D).

Roentgenograms of No. 6, which received 20 c.c. intraperitoneally, showed the peritoneal, diaphragmatic, and sub-sternal lymph channels packed with thorium.

Roentgenograms of No. 5, which unintentionally received 20 c.c. intra-intestinally, taken one-half hour, 20 hours, and six days, respectively, following injection, revealed that all the material had been eliminated from the intestinal tract. The increased density of the spleen indicated, however, that some of the thorium had been absorbed and stored in the reticulo-endothelial system.

The comparative roentgenograms (Figs. 2-A and 2-B) of a patient injected May 10, 1933, exhibited no change in density of the liver and spleen after a period of four years.

The results of these roentgenographic studies confirm those of many authors in demonstrating that the thorium is stored

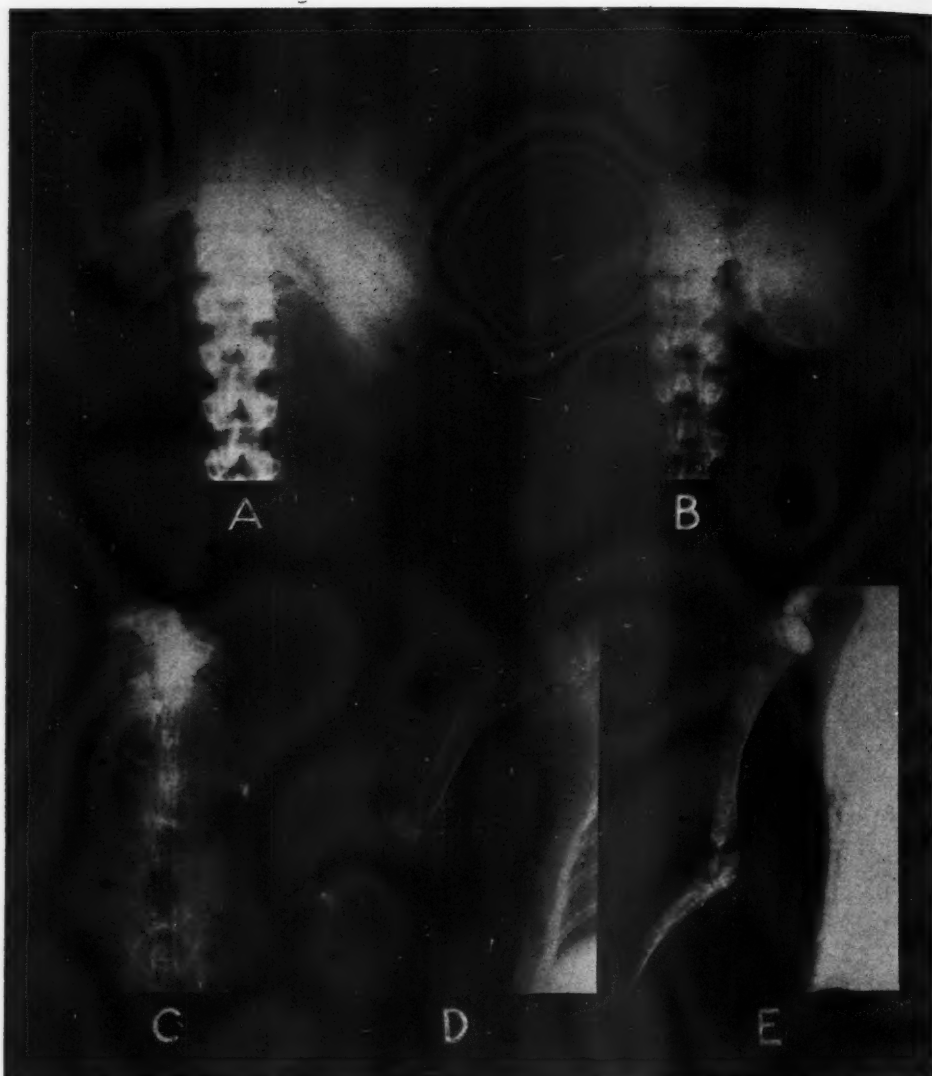


Fig. 2-A. Roentgenogram of a patient taken 24 hours after intravenous injection of 75 c.c. thorium dioxide sol.

Fig. 2-B. Roentgenogram of same patient taken four years later. Note liver markedly decreased in size and increased in density, also the peculiar concentration of the thorium in the hepatic trinity. Spleen shows no change in density.

Fig. 2-C. Roentgenogram of rabbit No. 16, two and one-half years after intravenous injection, 1.2 c.c. per kilogram body weight. Note granular appearance of liver and spleen due to thorium concentration.

Figs. 2-D-E. Roentgenograms of humerus of rabbit No. 13 (D), control, and No. 14 (E), three months after intravenous injection. Note the increased density of bone marrow (E) as compared with normal homogeneous density (D).

in the liver, spleen, and bone marrow, and that there is apparently no real elimination of the drug.

Changes in the body weight of the

injected animals and in the weights of liver and spleen as compared to those of uninjected animals were quite marked.

Rabbit No. 3 lost 25 per cent of its original

weight in a period of four and one-half months, a portion of which was undoubtedly due to an abortion of eight dead young two weeks after injection. No. 14 lost 140 grams after three months, while the control, No. 13, gained 310 grams. No. 16, which received a minimal dose, gained a maximum of 150 grams after two and one-half years and then lost 465 grams in the three months preceding death. These data would indicate that thorium dioxide sol so disturbed the body functions as to inhibit normal growth and nutrition.

The spleen of animal No. 12 increased both in weight and volume markedly over the control No. 11 after only 24 hours. It is to be noted that this was after injection of the minimal dose. The spleen and liver of No. 14, which was given a larger dose, showed a much greater increase over the control; the spleen being 130 per cent greater in weight and 80 per cent in volume, while the liver increased 10 per cent in weight and 11 per cent in volume.

From these data it would appear that, in spite of the loss of total body weight as compared to the control, the liver and spleen immobilized sufficient thorium to enlarge greatly both their relative and absolute weights and volumes.

PATHOLOGICAL FINDINGS, MICROSCOPIC

Liver.—The Kupffer cells in rabbit No. 12, which received the minimal dose, had engulfed the thorium, and the capillaries were hemorrhagically congested. Additional findings in a section of No. 9 (Fig. 3-A) were pronounced fat vacuolization, especially at the periphery of the lobules. The fibrous tissue septa were increased in size and contained thorium.

Sections of No. 3 (Fig. 3-B) which received a larger dose, showed a small amount of lymphatic infiltration of some of the bile ducts. Throughout the entire section there were numerous areas of healing focal central necrosis, filled with large masses of thorium surrounded by a moderate amount of pink-stained col-

lagenous fibers in which the nuclei, for the most part, were hyperplastic, ovoid, and pear-shaped. The adjacent hepatic cells presented two appearances: in the one group the cytoplasm was poorly defined and the nuclei were karyolytic; in the other group, which is the predominant one, the cells were larger than normal, well defined, and had prominent hyperchromatic nuclei.

In sections of No. 6 (Fig. 3-C) there was a definite increase of the fibrous connective tissue over that observed with smaller doses. One very distinct area of focal necrosis was seen deep within the liver substance. It was characterized by the deeper pink-staining cytoplasm of the involved cells, distinct karyolysis, pyknosis, and complete loss of outline of the nuclei. In other nuclei karyorrhexis was seen. The damaged cells contained thorium.

The section of No. 14 (Fig. 3-D) showed, in addition to many of the above characteristics, multiple areas of necrosis. There was a distinct increase in periportal connective tissue.

Spleen.—Sections of the spleen of No. 12 and No. 9, which received comparatively small doses, showed hemorrhagic congestion throughout the red pulp with the lymph venous sinuses largely filled with thorium. The periphery of the lymph follicles contained shiny refractile, brown violaceous staining granules indicating thorium. In relation to these there were large phagocytic cells, whose cytoplasm was laden with material of the same appearance.

In No. 14, (Fig. 3-E), which received a much larger dose, the only additional change noticed was an almost complete replacement of the tissue by the irregularly shaped large masses, which were presumably thorium.

Abdomen.—The abdomen showed no changes, except in rabbit No. 6 which had received a large dose intraperitoneally. The organs grossly were not remarkable, except for the presence of tiny yellow-gray points just discernible on the cut

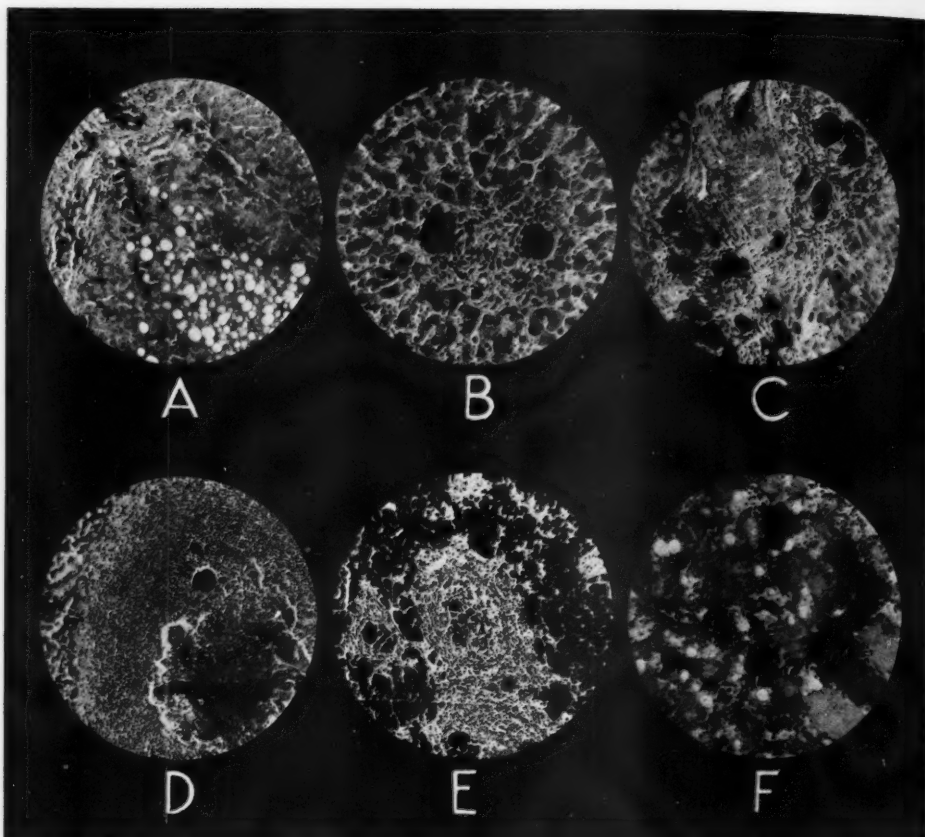


Fig. 3-A. Photomicroscopic section of liver (150 \times), rabbit No. 9, injected intraperitoneally with 8 c.c. of thorium dioxide sol, 12 months previously. Note accumulation of dark masses (thorium), increase in fat, and slight interlobular increase of fibrous connective tissue.

Fig. 3-B. Photomicroscopic section of liver (450 \times), rabbit No. 3, injected with 4.4 c.c. per kilogram body weight, four and one-half months before. Note the maturing granulation tissue about thorium dioxide masses. There is degeneration of some adjacent liver cells and hyperplasia of others.

Fig. 3-C. Photomicroscopic section of liver (250 \times), rabbit No. 6. Note aggregates of dark gray globules (thorium). There is very definite proliferation of fibrous connective tissue and a slight lymphocytic infiltration about the hepatic trinity. There is a hyperplasia of some hepatic cells at the periphery of lobules.

Fig. 3-D. Photomicroscopic section of liver (250 \times), rabbit No. 14, three months after intravenous injection of 4.4 c.c. per kilogram body weight. Note the large area of focal necrosis surrounded by well defined exudative inflammation which is, in turn, flanked by early productive inflammation.

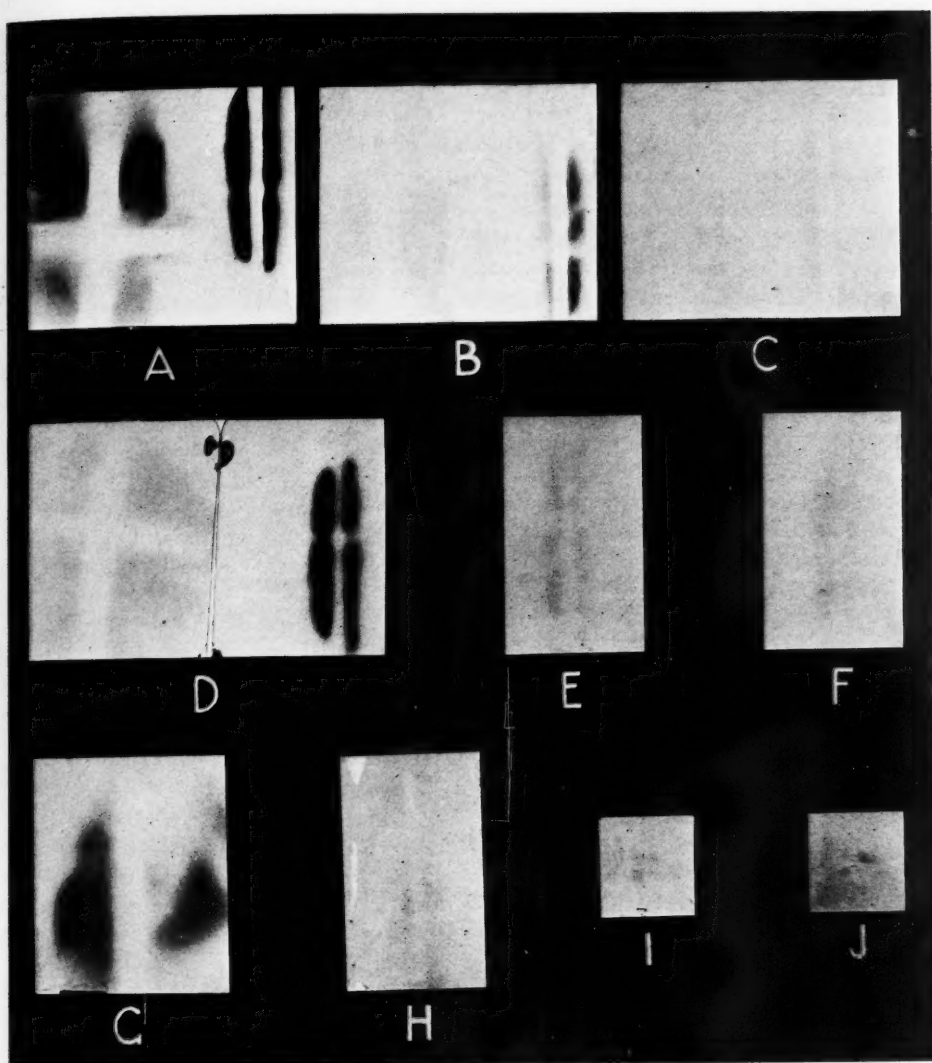
Fig. 3-E. Photomicroscopic section of spleen (250 \times), rabbit No. 14. Note the dark gray, irregular aggregates of thorium dioxide. The periphery of lymphoid follicles is degenerated and the central portions are hyperplastic. There is a slight amount of fibrosis.

Fig. 3-F. Photomicroscopic section of bone marrow of femur (150 \times), rabbit No. 6. Note the large and small dark masses of thorium and hemopoietic inactivity.

surface of the liver. The peritoneum, both parietal and visceral, was distended with large collections of thorium. The subserosa and voluntary muscles contained large, irregularly shaped phagocytic cells whose cytoplasm was laden with amorphous material of the same appear-

ance. The nuclei of such cells were poorly differentiated.

Bone Marrow.—Rabbit No. 6 (Fig. 3-F). The bone marrow contained collections of round and ovoid highly refractile violaceous bodies which appeared to be in the thin-walled sinusoids. There were



Figs. 4-A, 4-B, and 4-C. Shadowgrams of liver and spleen, rabbit No. 3. X-ray films exposed directly to dry specimens for 10 days, 40, and eight hours, respectively, with interposed lead cross.

Figs. 4-D, 4-E, and 4-F. Shadowgrams of same organs obtained through original wrapping plus 0.3 mm., 1 mm., and 2 mm., respectively, aluminum filter in six, two, and 20 days' exposure, respectively.

Fig. 4-G. Shadowgram of lung, rabbit No. 14, obtained in 60 days' exposure.

Fig. 4-H. Shadowgram of femur, rabbit No. 14, obtained in 60 days' exposure.

Figs. 4-I and 4-J. Histoshadowgrams of sections of liver and spleen, 10 micra thick, rabbits No. 3 and No. 14, respectively. Supersensitive panchromatic film exposed to deparaffinized microscopic section for 90 hours.

some phagocytic cells whose cytoplasm was loaded and distended with such granules, the nuclei being somewhat flattened.

Lungs.—The walls of the alveoli and interstitium contained masses of thorium engulfed by phagocytes. There was pro-

nounced edema but no inflammatory reaction.

Adrenals.—The adrenals contained thorium in the reticulo-endothelial cells. There was questionable degeneration of the cortical cells in the zona glomerulosa.

None of the controls showed any abnormalities whatsoever.

The histological findings here reported are practically identical with those reported by Whitaker, Davie, and Murgatroyd (58).

RADIO-ACTIVITY

As previously stated, Prof. R. D. Evans measured for us the radio-activity of an ampule of thorium dioxide sol and found it to be equivalent to 0.25 microgram of radium when measured through 10 mm. of lead.

Rabbit No. 12, which received approximately 10 per cent of one ampule, was taken to Cambridge, Aug. 27, 1937, where the radio-activity of the live rabbit was measured by Professor Evans. The rabbit died the following day. An autopsy was performed and the dried material sent to Professor Evans. Both the live rabbit and the dried material showed 50 ± 50 per cent retention. The large uncertainty is due to the fact that the 0.025 microgram of radio-active material injected approaches the lowest limit that can be detected by gamma-ray measurements.

The radio-activity of the sol and of injected specimens was demonstrated in this laboratory by means of photographic films and the spinthariscopes.

Roentgen films were exposed to a commercial ampule of the sol; after eight days there was a marked fogging on the emulsion, the shadow clearly outlining the ampule.

The liver and spleen of rabbit No. 3 were dried and placed directly over a film with lead strips interposed between the film and the specimens to produce contrast. Distinct shadows were produced by exposures ranging from 45 days down to two hours (Figs. 4-A, 4-B, 4-C), and a faint shadow was also obtained in only one hour. These pictures, after Martland (79), are called "shadowgrams." The lungs (Fig. 4-G) and the femur (Fig. 4-H) of rabbit No. 14 also gave definite shadowgrams.

To eliminate the alpha radiation, dental occlusal films in their original covers were exposed to the same specimens. Intense shadowgrams were obtained after five days' exposure.

The relative strength of the penetrative radiation was demonstrated by placing aluminum filters ranging in thickness from 0.3 mm. to 2 mm. between the specimens and the films. Definite shadowgrams were obtained with 0.3, 0.5, and 1 mm. of aluminum in two days and with 2 mm. of aluminum in 20 days (Figs. 4-D, 4-E, and 4-F).

Histologic sections of the liver of No. 3 and the spleen of No. 14, ten micra thick, were deparaffinized and dried on slides. Fast panchromatic films were exposed to these slides and after 90 hours definite histoshadowgrams were obtained (Figs. 4-I and 4-J).

The presence of alpha radiation was demonstrated by placing a small bit of the dried spleen of No. 3 in a spinthariscopes. The large number of scintillations produced on the screen demonstrated clearly the presence of alpha particles.

It is thus evident that if there is sufficient radio-activity to produce the above effects, then this radio-activity would produce a continuous bombardment of the cells in the body tissues wherein it became lodged.

SUMMARY

1. Injected thorium is engulfed by the reticulo-endothelial system, *i.e.*, the reticulum cells of the splenic pulp, lymphatic tissue, and bone marrow, the endothelial cells of the liver capillaries (Kupffer cells), lymph sinuses, splenic sinuses, bone marrow, and suprarenal capillaries, and the phagocytic cells in connective tissue.

2. There has been no evidence of elimination of this substance from the body during a four-year period of observation. This apparently results in a permanent blockage of the reticulo-endothelial system, and may thus impair its immunologic properties.

3. Thorium dioxide sol has been demonstrated, by means of shadowgrams, to be definitely radio-active in both prepared ampules and when engulfed in body tissues. Even minute amounts of injected tissue have been shown to be radio-active by means of histoshadowgrams and by the spinthariscopes. The use of filters has shown that both alpha and gamma radiation are present.

4. The following histologic changes have invariably been found:

(a) The reticulo-endothelial system phagocytoses the thorium dioxide.

(b) The liver shows pathologic changes varying from simple cloudy swelling to profound necrosis, depending upon the dose. These changes are followed by fibrous tissue proliferation giving a picture similar to mild nodular hyperplastic cirrhosis.

(c) The spleen shows damage varying from degeneration of the lymph follicles to marked necrosis, even of the vessels and interstitium.

(d) The bone marrow contains large clusters of thorium and shows hematopoietic depression.

(e) The lung histocytes contain thorium with no definite tissue damage.

(f) The adrenals contain thorium in the reticulo-endothelial cells. There is questionable degeneration of the cortical cells in the zona glomerulosa.

CONCLUSIONS

We believe that thorium dioxide sol should not be injected into human beings because:

1. It is not eliminated from the body.

2. It apparently blockades the reticulo-endothelial system and may thus adversely affect some of the body's immunity mechanism.

3. It may, as in our experimental animals, profoundly damage the liver and spleen parenchyma, with early and late degenerative changes.

4. It is a radio-active substance, and undoubtedly has dangerous cumulative radio-active effects.

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PERIPHERAL BLOOD PHENOMENA AND DIFFERENTIAL RESPONSE OF BONE MARROW AND LYMPH NODES TO HYPERPYREXIA¹

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THE importance of the cellular elements of the blood and connective tissues to the maintenance of health and the control of disease has been increasingly apparent since the early studies of Metchnikoff. It is now recognized that every circumstance which affects the complex mammalian body affects the hemolytotoxic mechanism, in some degree, for "weal or woe." Most assuredly is this true of all physical or physico-chemical agents. Deep x-ray, the gamma rays of radium, mesothorium, thorium X, and other radio-active substances are now known, after a costly toll of scientific and industrial lives, to have a special destructive affinity for the hemopoietic tissues. Lymphatic tissues are perhaps the most susceptible, while myelopoiesis and erythrocytogenesis show a variable latent period before the destructive effect becomes apparent.

Personal observations at the Rockefeller Institute (1) with the introduction of radium chloride and mesothorium in small dosage in rabbits over a prolonged period (more than a year) resulted not only in the progressive destruction and inhibition of cytogenesis in lymph nodes and bone marrow, but in two instances osteogenic sarcomas developed terminally.

The question as to whether under favorable circumstances these physical agents may ever be primarily stimulatory has long been debated. "Stimulating" doses ($1/20$ S.E.D., 39 r units) of x-ray have been advocated in agranulocytic angina, for example (2). It has been our experience (3, 4), however, that under

experimental conditions one single x-ray exposure, of even smaller dosage (19 r units) invariably produced definite nuclear chromatin degeneration in individual myelocytes throughout the femoral marrow in pigeons, as observed at the end of 24 hours.

Knowing these facts about the cells of the blood and their sites of origin, it becomes important to analyze and to appraise the effect of any new therapeutic procedure upon these important accessories to the total defense forces and strategy of the body in disease. Wherefore, the present study of the development, the distribution, and the functional efficiency of the cellular forces of the body as influenced by "fever," induced by the various means which have been advocated and are being used to-day in modern medical practice. Through the interest of Professor Dreesse, and with the co-operation of Professor Byrne, of the Department of Electrical Engineering, Ohio State University, a high frequency, short wave radiotherm was constructed, installed in the Medical Research laboratories, and a comprehensive and extensive series of studies in rabbits was undertaken in 1932. In April, 1934, through the courtesy of Mr. Charles F. Kettering and Dr. Walter Simpson, an air-conditioned fever cabinet, the Kettering Hypertherm, was installed on the Research Service, the University Hospital, making it possible to extend our studies of the cellular reactions during artificially induced hyperpyrexia to selected human patients. Meantime, similar cellular studies have been made for comparison and contrast, during fever episodes induced by the intravenous inoculation of typhoid vaccine, and by malaria inoculata. In several instances the same patients were sub-

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² Dr. Malcolm M. Hargraves was associated in the fever studies, and Miss Lucile Kester, R.N., was the nurse technician in charge of the Kettering Hypertherm cabinet.

jected to all three methods of fever induction, a suitable interval having intervened between each (5).

TECHNICS EMPLOYED

Previous studies of the white blood cells have demonstrated the frequent physiologic fluctuations which occur, and which reflect at times redistribution, and at times bone marrow and lymph node delivery phenomena, in the peripheral circulation. The sensitive lability of the leukocyte response in disease, and to any physiological or chemical disturbance, has been repeatedly demonstrated in recent years. Any study, therefore, of the influence of induced hyperpyrexia upon the cellular equilibria of the blood must presuppose an adequate base line of frequently repeated successive observations (every 15 to 20 minutes), such counts being continued throughout the actual fever episode, and as long as any significant qualitative as well as quantitative alterations in the cells remain—sometimes a 24- to 36-hour period.

The technics employed were standardized throughout. The marginal ear veins were used for the collection of blood samples in the rabbits. Capillary blood from a uniformly deep automatic lancet puncture of the finger furnished the samples each time from patients, except during the actual cabinet period, when the ear was used. These sources have been proved to reflect with equal sensitivity any significant changes in the cellular concentration of the peripheral blood. After discarding the first drop of blood, supravital and fixed cover slip blood films, total white count, total red count, and hemoglobin were always taken in the order named. Intravenous blood samples were taken at less frequent intervals for sedimentation, cell volume, and plasma volume (dye method) determinations. The Wright-Giemsa staining technic was applied to the fixed blood films for permanent record, and all Arneth-Schilling neutrophil and Wiseman lymphocyte qualita-

tive differential counts were made from these preparations.

RADIOTHERM AND HYPERTHERM

Experimental Observations.—The hemogram which accompanies and follows the febrile state was first established in the radiotherm, and later confirmed in the Kettering hypertherm, using normal adult rabbits as subjects. No essential difference in the cellular responses has been noted in comparing these two methods of fever induction.

During the period of maintained hyperpyrexia (108° to 109.8° F.) a definite and usually marked leukopenia develops. The circulating lymphocytic elements are invariably reduced, the granulocytes, in the majority of instances, also participating in the general reduction in total white cells. This diminution of white cells in the blood stream continues as long as the fever is maintained—up to 23 hours in one experiment in this series. Qualitatively, the granulocytes may "shift to the right" with increased nuclear lobes at the onset of fever and neutropenia. Later a marked decrease in the "lobe index" or Arneth-Schilling "left shift" reflects the marrow delivery of less mature elements. If the period of fever is limited to a few hours and the temperature has been kept within sublethal limits, the regenerative potentialities of the bone marrow in the individual animal under observation is measured by the height of the leukocytosis which is attained during the succeeding 24 hours. The neutrophilic granulocytes respond first, rising reciprocally as the temperature falls, the lymphocytes returning to the circulation only considerably later. As with the neutrophils, so do the lymphocytes reflect the regenerative activity at their sites of formation as they reappear in the circulation—with basophilic cytoplasm, abundant mitochondria and vesicular nuclei, significant of a post-febrile hyperplasia of the germinal centers in the lymph nodes.

Comparative studies of lymph nodes and bone marrow, taken at biopsy, with

postmortem surveys of the tissues after varying periods of hyperpyrexia, reveal the double mechanism of cell emigration into the tissues and cell destruction and regenerative inhibition as responsible for the leukopenia. In a series of nine rabbits febrile for varying periods from 50 minutes to 23 hours and autopsied immediately thereafter (see Table I), degenerating and fragmenting lymphocytes were found as a prominent feature in the lymph nodes of all. Even with the shorter periods of fever the evidence of lymphocyte destruction was immediate and striking. After longer periods of sustained fever a progressive hypoplasia of the lymphatic tissues developed, with marked infiltration of neutrophilic granulocytes, endothelial hyperplasia and desquamation, with the appearance of great numbers of phagocytic clasmatocytes. As observed in other series of animals in which survival permitted eventual cellular regeneration, lymphopoiesis did not become effective for some hours following the return of the temperatures to normal.

The bone marrow behaved rather dif-

ferently. The criteria of cell degeneration and disintegration were most prominent in the early minutes or hour of temperature elevation, to be followed promptly by evidence of regeneration with increased numbers of mitotic figures in the myeloid foci and increasing myelopoietic hyperplasia at the expense of the marrow fat cells, even without deferescence of the fever. An increased delivery of granulocytes to the circulation was apparent from the dilated sinuses and depleted myeloid reservoirs. This has been further demonstrated by differential counts of the myeloid-erythroid cell ratio in serial marrow samplings. After 23 hours of continuous fever at 108° to 109° F. the myeloid hyperplasia, with only equivocal evidence of cell destruction and no increase in phagocytic clasmatocytes, was in sharp contrast to the findings in the lymph nodes and other tissues of the same animal.

It would seem, therefore, that the lymphopenia during fever in the rabbit reflects both a destruction of lymphocytes and an inhibition of lymphopoiesis; the

TABLE I.—BONE MARROW AND LYMPH NODE REACTIONS TO VARYING PERIODS OF CONTINUOUS FEVER

Rabbit No.	Biopsy: Lymph Node and B.M.	Duration of Fever above 105° F.	Method of Fever Induction	Lymph Nodes			Bone Marrow		
				Lymphocytes: Degeneration and Fragmentation	Polymorpho-nuclear Infiltration	Clasmato-cyte Reaction	Cell De-generation and Frag-mentation	Myeloid Hyper-plasia with Mitosis	Clasmato-cyte Reaction
458	No	50 min.	R	+ to +++	±	±	++++	+	0
457	Yes	1 hr.	R	+	0	+	0	±	0
446	Yes	1½ hr.	R	++++	+	±	0	++	0
448	Yes	2¼ hr.	H	+++	0	++	+++	+	±
459	Yes	2½ hr.	H	++++	++	+++	0	++	0
438	Yes	3 hr.	R	+++	++	+++	±	++	0
453	Yes	5 hr.	R	++ (hypoplasia)	++++	+++	++	++	+
413	No	10 hr.	R	+++ (hypoplasia)	+++	+++	++	++	0
469	No	24 hr.	R	+ (hypoplasia) (no regeneration)	+++	++++	±	+++	0

granulopenia initially may represent some destructive effect of the rising temperature upon myeloid cells, but soon the marrow adjusts and increases its output with a corresponding relative increase in circulating young forms. During the continuation of fever, however, this marrow activity has never been observed to result in a leukocytosis, because of the rapid exodus of the cells from the blood stream into the tissues. If and when the high temperatures begin to subside, the granulocytes rapidly increase in the circulating blood, reaching a high point during the succeeding 24 hours, and showing a return to a more right-sided shift as the equilibria become re-established.

The monocytes in the normal rabbit seem to participate in only a minor degree in the uncomplicated reaction to simple fever. If, however, fever be administered to a tuberculous rabbit, a very different hemogram is observed, the increased monocyte-epithelioid content of the tuberculous tissues being reflected by a high monocyte rise in the blood, with more rapid dissemination of the disease and toxic symptoms and hemorrhage in excess of the control animals (6).

Insofar as the cellular equilibria in rabbits are concerned, therefore, fever *per se* destroys and inhibits lymphocytic elements in direct proportion to the height and duration of the temperature. A marked infiltration of polymorphonuclear leukocytes occurs in the lymph nodes and a great increase is noted in highly phagocytic clasmatoocytes; granulopoiesis, on the other hand, is stimulated, but qualitative changes in the circulating cells and a study of the bone marrow for generative activity and the general connective tissues for leukocytic infiltration provide the evidence, rather than a peripheral leukocytosis. In any pathologic condition, therefore, in which a reduction in lymphocytic accumulations in the tissues is desirable, and in which the phagocytic activity of clasmatoocytes and the defense potentialities of neutrophilic granulocytes are theoretically desirable, the judicious

use of fever might be considered a rational procedure.

HYPERTHERM STUDIES IN SELECTED HUMAN PATIENTS

In the human subject the preliminary leukopenia just described, is often absent, with the leukocytosis starting from the pre-febrile level in from three to seven hours after the induction of fever. The degree of leukocytosis varies from individual to individual and in the same patient from treatment to treatment. The total white count has varied in our experience from 10,000 to 60,000. The initial cellular response is made up primarily of neutrophilic polymorphonuclear leukocytes. The most striking thing about this early phase of the reaction is the irregularity in the curve of total white cells. The increase in cells does not progress smoothly and steadily upward, but rather by irregular fluctuations, producing marked peaks and depressions which at times reflect as much as a 30,000 difference in cell level in a 20-minute period. By such tide-like variations, the peak of leukocytosis is finally reached. Occasionally there are two or three such peaks divided by intervening low points. The curve of the total white blood count gradually declines in the same manner as it ascended, with not infrequently a less marked secondary leukocyte peak which follows some hours after the original maximum point. Inasmuch as this is largely a neutrophilic response, Arneth-Schilling counts were carefully made to analyze the findings and interpret the results. In going over the data it seemed important to attempt to recognize small changes in the bone marrow delivery of granulocytes, that the mechanism of response might be more accurately appraised. The usual Arneth-Schilling indices seemed at times less sensitive than desired, so that a method of expression for the "left shift" was devised, which might be termed the "Lobe Index." That the number of lobes in an individual granulocyte may be interpreted in terms of the relative age of the cell has

been repeatedly proved. The total number of lobes noted while counting 100 neutrophilic leukocytes should then reflect the relative degree of average maturity at which the cells at any given time are circulating in the blood. Theoretically, the greatest possible "shift to the left" would be indicated by 100 lobes, each cell then being a "band form" or myelocyte; conversely, if all granulocytes had five distinct lobes the total for 100 cells would be 500, an extreme degree of "right shift" for the bone marrow. Taking this index before fevering each time as a base line, it has been found that there is a "shift to the left" as expressed by a fall in the Lobe Index curve as leukocytosis progresses. This is indicative of an increased bone marrow delivery of granulocytes and not simply the release of cells from reserve depots. As the leukocytosis declines there is a gradual shift to the right to the pre-fevering index.

The lymphocytes early are depressed to a very low level (200 to 500 cells) as the fever rises. There is rarely an initial lymphocytosis, made up of mature and older lymphocytes, which usually rapidly disappear from the blood. Occasionally during fevering there are small wave-like reappearances of lymphocytes which again promptly subside; these lymphocytes are uniformly young cells. The main lymphocytic response comes from 10 to 18 hours after the height of the fever. This is the last cell type to increase in the peripheral blood. These returning cells are invariably young, many lymphoblasts being scattered among young, deeply basophilic lymphocytes. We believe that all indications so far point to a destruction of lymphocytic elements during hyperpyrexia, with a regeneration and delivery of new lymphocytes to the peripheral blood in the post-febrile period.

There is also a depression of the monocyte count in the human subject during the early stages of fever, with a secondary monocytosis following about 9 to 12 hours later. These cells make their reappearance usually with the decline of the granulocy-

tosis, although there are occasional tide-like deliveries when the leukocytosis is at its peak. The monocytes found after fever are very definitely younger cells than those in the circulation before fever and they make their appearance in periodic showers. No increase in phagocytic activity was noted in these cells.

Having established a febrile hemogram with the foregoing characteristics, an attempt was made to study the effect of duration and height of temperature on this cellular reaction. When an individual who had a typical hemogram following five hours of fever at 106° was subjected to five hours of fever not surpassing 101.4° , but with definite vasodilation and sweating, the hemogram showed only the fluctuation which one would expect from ordinary temporal variations. Another individual, who had had a typical hemogram with a five-hour fevering, when given ten continuous hours of the same type of fevering showed only a questionable prolongation of the period of leukocytosis. The same individual subjected to a rapid rise in temperature up to 108° F., but not sustained, gave a cellular response almost identical in degree and duration with that observed following five hours at 105° F. Repetition of these variations in another individual gave similar results.

In order to determine whether this increase in circulating cells might be related to splenic contraction, to cyanosis, to excitement, or to a combination of these factors, certain pertinent observations were made. One individual, who previously with fever had given a leukocytosis between 40,000 and 60,000, was subjected to an "adrenalin test." Peripheral blood counts were taken every 15 minutes for one hour before the administration of 1 c.c. of 1:1,000 solution of adrenalin intramuscularly. Successive short interval counts thereafter during the period of induced splenic contraction showed little change in the blood picture other than a moderate increase in lymphocytes. There was nothing comparable to the fluctuation shown

in the febrile hemogram from this same patient. To further check the splenic influence on this hemogram, an individual who had previously (February, 1934) been splenectomized, was given four hours of fever between 106° and 107° F. A leukocytosis of 50,000 was reached by the same tide-like variations as in normal individuals. The only marked difference noted was the longer period during which the leukocytosis was sustained, returning slowly toward the pre-febrile base line over a 36-hour period.

Inasmuch as cyanosis is recognized as a stimulus to the spleen and bone marrow, its unexpected development in an individual whose hemogram had previously been determined during the usual course of fever provided the basis for a comparative hematologic study. This individual while taking his sixth hyperthermic treatment, became markedly excited during the induction stage, the incident culminating in a typical epileptiform seizure and the development of a very marked cyanosis. Upon removal from the cabinet, and following the intravenous administration of stimulants, the patient promptly recovered and seemingly returned to his pre-febrile state of rationality. During the time out of the cabinet his temperature fell to normal. Thinking it was safe to continue his treatment, he was again placed in the cabinet, and his systemic temperature was carried upward through the excitement stage. At this point he again developed marked restlessness and his convulsion recurred with the reappearance of the same intensity of cyanosis. He was immediately removed from the cabinet and no more fever therapy has been attempted in this patient. During these episodes just cited, blood counts were taken every 15 to 20 minutes, and no significant effect was noted which could be attributed either to the cyanosis, to excitement, or to the convulsions in his curve of leukocytosis. The patient did, however, develop a leukocytosis in proportion to the amount of fever which he had carried.

FEVER INDUCED BY INTRAVENOUS TYPHOID VACCINE

The febrile hemogram resulting from intravenous typhoid vaccine injections is similar to that observed with the hypertherm. In this study killed *Bacillus typhosus* organisms suspended in normal saline were used for the induction of the chill and fever, the same routine of blood cell counting being followed as in the hypertherm studies. The most noteworthy variation is the marked leukopenia which develops with the onset of the chill and which persists throughout its duration. There is marked peripheral vaso-constriction combined with muscular activity which occurs during the chill, and it is interesting to compare the effect of this peripheral cyanosis with the generalized cyanosis in the patient with convulsions mentioned above. Here a marked leukopenia was reflected in the granulocytes and monocytes; in the other instance there was no appreciable change in the blood cell equilibria. The peripheral vaso-constriction is probably an important factor in the production of this phenomenon. The granulocytes uniformly fall to a very low level, with a total count of between 2,500 and 4,000, while the monocytes completely disappear from the circulation and remain persistently absent for from three to eight hours. The neutrophils, however, rapidly return to the peripheral circulation with the passing of the chill and climb to a leukocytic peak which is in all respects comparable to other febrile hemograms. When these neutrophils are studied with the Arneth-differential using the Lobe Index, we find that there is a moderate shift to the left which, as time goes on, becomes more and more apparent. The shift to the left in this hemogram is far more pronounced than that seen in the hypertherm-induced reaction and with each new influx of cells there is a corresponding drop in the Lobe Index. The monocytes upon return to the circulation are young and moderately stimulated, and the stimulation of these cells, as shown by the formation of neutral red-stained vacuoles in their cytoplasm, is more

marked than that seen in the hyperthermia-induced monocytosis. The fluctuations and qualitative changes in the lymphocytes are not unlike those observed following the delayed hyperthermia lymphocytosis.

Studies were made of this type of fever induction to determine the effect on the hemogram of variations in temperature range and the number of organisms injected and there seemed to be no correlation of either. A temperature of 100.4° induced by fifty million organisms was accompanied by as high a total white count as followed a temperature of 105° with fifty million organisms. The persistence of the leukocytosis with the higher temperature was a little longer than that with the lower temperature, as it was in the hyperthermia experiment.

FEVER INDUCED BY MALARIA INOCULATA

The hemogram produced by malaria is distinctive. The most noticeable thing is a fall in total white count during the incubation period to give a patient, who, before inoculation, had carried a high normal count, a very marked leukopenia. The polymorphonuclear leukocytes are markedly shifted to the left with the majority of cells being one-lobed, while occasional metamyelocytes and myelocytes C are encountered. The leukocytosis induced by the hyperpyrexia following a chill is comparatively small, seldom going over 14,000 or 15,000 in a patient who had previously given and who subsequently gave a leukocytosis of 40,000 to 60,000 with the hyperthermia. The lymphocytes follow the same general trend as in other febrile hemograms with the exception that lymphoblasts are more numerous and extremely young lymphocytes dominate in the secondary lymphocytosis which follows the fever period. The monocytes are most strikingly altered in their qualitative characteristics. They return to the circulation to make at times 30 to 40 per cent of the total count and are extremely young and markedly stimulated. The entire age range for this cell type can be seen, from monoblasts to mature monocytes, and the cells vary in size markedly,

the majority being much larger than those normally seen in the peripheral blood. The vacuolization is not that of the rosette formation as seen in the epithelioid type of monocyte, but is rather a diffuse scattering of enlarging vacuoles throughout the increased quantity of cytoplasm. There is a marked diminution of lymphocytes and monocytes during the chill with resultant leukopenia. During the period of monocytosis there also appears in the peripheral blood an abnormal number of actively phagocytic clasmatoocytes. They have been seen in same counts as high as 7 and 8 per cent, and this has been observed in no febrile hemogram induced by agents other than malaria.

HUMAN BONE MARROW BIOPSY STUDIES

Serial sternal bone marrow biopsies were done on one patient who was subjected to hyperthermia fevering first, and, then, after an adequate rest period, was inoculated with malaria. The first biopsy was done before any therapy and during a period of observation. It showed a normal bone marrow picture by actual differential count of cells in supravital preparations. The second biopsy was done over a month later at the completion of the patient's third hyperthermia treatment, just after removal from the cabinet. The differential marrow count at this time was practically identical with that of the first. The third biopsy was done after the completion of eight malarial paroxysms, and there was a striking difference in the marrow picture. A marked "shift to the left" in the myeloid elements was shown by a significant increase in the myelocytes B and myelocytes A at the expense of the normally dominant myelocytes C. There was also a "shift to the left" in the erythroid elements. The appearance of plasma cells and a marked increase in highly phagocytic clasmatoocytes was outstanding.

CONCLUSIONS

In conclusion, we may say that there is a rather constant hemopoietic response to "fever" and that the majority of the cells

making up the post-febrile leukocytosis are polymorphonuclear neutrophils newly delivered by the bone marrow as shown by their youth. This part of the reaction may be non-specific and is by no means necessarily the most important from the standpoint of the fundamental body defenses. There is a destruction of lymphocytes during hyperpyrexia, as attested by the lymph node studies cited and by the return to the circulation, after a prolonged lymphopenia of very young cells. There is probably in the human patient some destruction or redistribution of monocytes as is shown by a delayed monocytosis made up primarily of younger forms. The hemograms following malaria and *B. typhosis* inoculations differ from those observed during fever induced by physical methods in the marked leukopenia during the chill, in the temporary disappearance of the monocyte from the circulation following typhoid, and in the marked stimulation of the monocyte in malaria and its moderate stimulation following typhoid vaccine. The shift to the left in the neutrophilic granulocytes in malaria is outstanding and the appearance of clasmatoctes in the peripheral blood has been observed with no other type of fever study.

It has been suggested by Breutsch that the profound stimulation of phagocytic clasmatoctes observed in malaria, as the result of red cell destruction by the plasmodia, provides an important cellular defense weapon in the treatment of central nervous system syphilis, which is not available when other fevering methods are employed. Cunningham has emphasized the importance of clasmatoctes in the control of experimental syphilis in rabbits. While it is true that the sternal marrow biopsy

studies in the human patients cited, and the rabbit bone marrows studied postmortem following hypertherm fever therapy did not show an increase in clasmatoctes, we would call attention to the tremendous increase in these phagocytic cells elsewhere in the tissues, more especially in lymph nodes, spleen, and liver. To that extent, at least, artificial hyperthermia by physical means not only provides the thermal factor of importance for the inactivation of the treponema pallidum and the gonococcus, but has now been demonstrated to exert a profound effect upon the cellular equilibria of the body—in the directions which we believe, at the present time, to be the most effective in the mobilization of the defense forces of the body against these diseases. In short, hyperpyrexia acts as a two-edged sword cutting both ways in its rôle as "assistant extraordinary" to the humoral defense mechanisms of the body.

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THE ROENTGEN VISUALIZATION OF CRANIAL NERVES AFTER INTRACISTERNAL INJECTION OF THOROTRAST

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THE present communication will describe a method for decalcifying bones of the skull which has made roentgen visualization of the intracranial structures possible. We believe the method may be of value in the study of certain experimental problems in animals, as it has allowed us to demonstrate thorotrast within perineural sheathes of certain cranial nerves. Thirty albino rats and eight cats were used for these experiments.

Previous studies concerning hypertension following intracisternal kaolin injection in rats have suggested that kaolin blocks perineural channels. During the course of these experiments, we (J. Q. G. and W. A. J.) repeatedly noticed that thorotrast injected intracisternally appeared in the cervical lymph nodes in normal rats soon after infection, whereas those rats in which kaolin had been injected previously failed to demonstrate similar perineural extension. While these experiments suggested that kaolin blocked perineural channels, roentgen evidence of this intracranial block could not be obtained due to the density of the bones of the skull, which made visualization of delicate thorotrast-filled structures impossible.

METHOD

(A) *Rats*.—Under ether anesthesia, cisternal puncture was performed and approximately 0.04 c.c. of cerebrospinal fluid withdrawn and a corresponding amount of thorotrast injected. Animals were decapitated under ether anesthesia at intervals varying from five minutes to 48 hours after injection. After removing the mandible and soft tissues, the heads

were decalcified by submerging them in 100 c.c. of 3 per cent hydrochloric acid, changing the acid twice daily. Decalcification was usually complete in three days, following which roentgenograms were taken.

(B) *Cats*.—The procedure was similar except: (1) 0.5 c.c. of spinal fluid was withdrawn and 0.5 c.c. of thorotrast injected into the cisterna; (2) decalcification required from two to three weeks in approximately a pint of the dilute hydrochloric acid.

RESULTS

As the cat is larger than the rat, we chose roentgenograms of cats for more convenient illustration.

Under normal conditions, the skull bones conceal thorotrast-containing structures within the calvarium. Following decalcification, the physical features of the skull may be identified but the soft parts can not be differentiated roentgenographically (Fig. 1). Thorotrast, injected during life, is immediately disseminated over the brain, allowing visualization of the convolutional markings (Fig. 2). Animals allowed to live about thirty minutes before decapitation show roentgen evidence (Fig. 3) of thorotrast along certain cranial nerves. (This has been confirmed microscopically by identifying thorotrast within the perineural spaces.)

Olfactory nerves, commonly seen roentgenographically in rats, are rarely demonstrated in cats. The optic nerves are visualized in both animals (Fig. 4). These nerves, when viewed stereoscopically, may be followed throughout their course from the chiasm to the optic disks, where they end abruptly. They are not so well visualized in animals allowed to live over one

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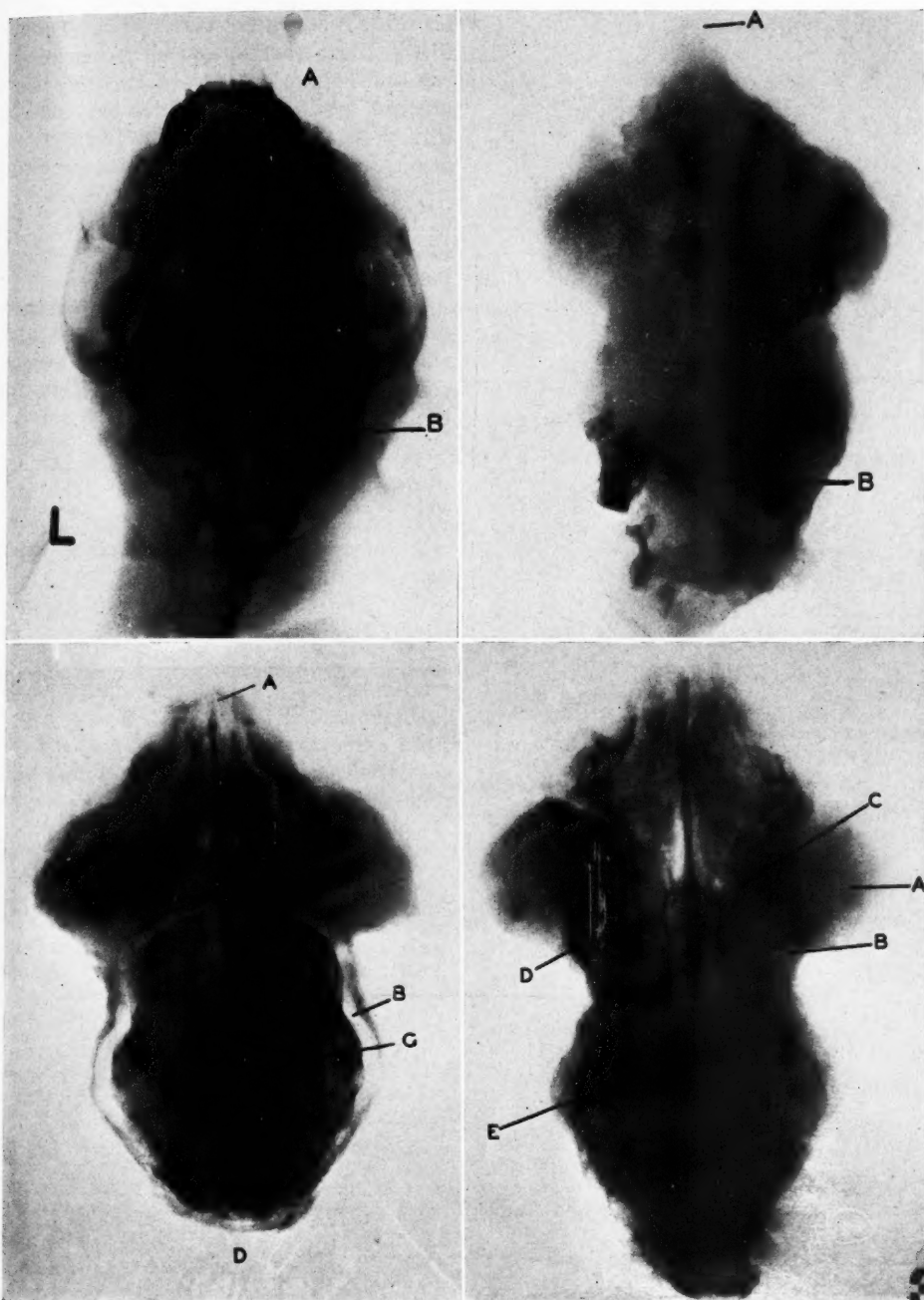


Fig. 1 (*upper left*). Cat: normal appearance of skull. (A) Nose; (B) Occiput.

Fig. 2 (*upper right*). Demineralized skull of cat illustrated in Figure 1. (A) Nose; (B) Occiput.

Fig. 3 (*lower left*). Cat: thorotrast injected and cat sacrificed soon after; skull demineralized. (A) Nose; (B) Subdural air; (C) Thorotrast in subarachnoid space.

Fig. 4 (*lower right*). Cat: thorotrast injected and cat sacrificed one hour after injection. (A) Eye; (B) Optic nerve; (C) Olfactory nerves; (D) Optic disc; (E) Convolutional markings.

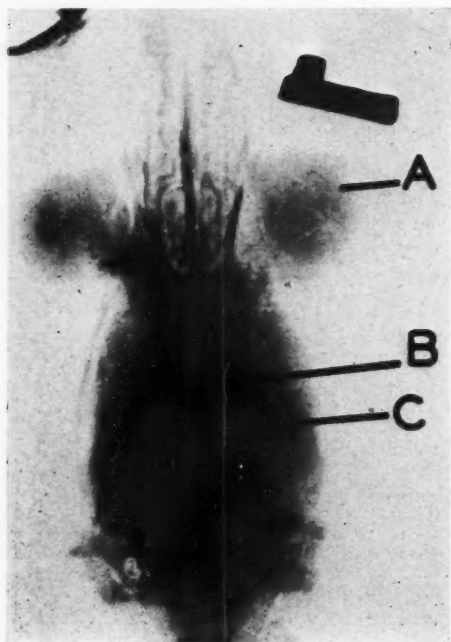


Fig. 5. Rat: kaolin previously injected to produce hypertension. Note ventricular detail. (A) Eye; (B) Lateral ventricle; (C) Posterior portion of lateral ventricle.

hour, although the disk region may retain its opacity for 48 hours after injection. Other cranial nerves, although less distinct, have also been demonstrated. In rats, one can occasionally recognize the shadows of the trunks of the fifth and

eighth nerves with ease. The shadows of the third, fourth, and sixth nerves and the ophthalmic division of the fifth nerve are not easily identified because they lie in a group close to one another. This is also true of the tenth, eleventh, and twelfth nerves which form a separate group. None of these nerves with the exception of the optic and perhaps the olfactory nerves, can be demonstrated in cats.

The roentgen findings were distinctly different in animals made hypertensive with kaolin in that these animals failed to show evidence of perineural extension and cranial nerve visualization (Fig. 5).

SUMMARY

1. Attempts to demonstrate intracranial structures in undecalcified skulls have been unsuccessful.
2. Thorotrast injected into the cisterna magna in rats and cats may be demonstrated in the sheathes of certain cranial nerves roentgenographically in decalcified skulls.
3. Thorotrast does not pass to the sheathes of the cranial nerves following a previous intracisternal injection of kaolin.

BIBLIOGRAPHY

- (1). GRIFFITH, J. Q., JR., JEFFERS, W. A., and LINDAUER, M. A.: *Am. Jour. Physiol.*, October, 1935, 113, 285.

RADIOLOGICAL SOCIETIES IN THE UNITED STATES

Editor's Note.—Will secretaries of societies please cooperate with the Editor by supplying him with information for this section.

CALIFORNIA

California Medical Association, Section on Radiology.—Chairman, John D. Lawson, M.D., 1306 California State Bldg., Sacramento; Secretary, Karl M. Bonoff, M.D., 1930 Wilshire Blvd., Los Angeles. Meets annually with California Medical Association.

Los Angeles County Medical Association, Radiological Section.—President, John F. Chapman, M.D., 65 N. Madison Ave., Pasadena; Vice-president, E. N. Liljedahl, M.D., 1241 Shatto St.; Secretary, Merl L. Pindell, M.D., 678 South Ferris Ave.; Treasurer, Henry Snure, M.D., 1414 Hope Street. Meets every second Wednesday of month at County Society Building.

Pacific Roentgen Club.—Chairman, Raymond G. Taylor, M.D., 1212 Shatto St., Los Angeles; Secretary, L. Henry Garland, M.D., 450 Sutter St., San Francisco.

San Francisco Radiological Society.—Secretary, L. H. Garland, M.D., 450 Sutter Street. Meets monthly on first Monday at 7:45 P.M., alternately at Toland Hall and Lane Hall.

COLORADO

Denver Radiological Club.—President, John S. Bouslog, M.D., 246 Metropolitan Bldg.; Vice-president, Sanford Withers, M.D., 304 Republic Bldg.; Secretary, Ernst A. Schmidt, M.D., Colorado General Hospital; Treasurer, H. P. Brandenburg, M.D., 155 Metropolitan Bldg. Meets third Tuesday of each month at homes of members.

CONNECTICUT

Connecticut State Medical Society, Section on Radiology.—Chairman, Kenneth K. Kinney, M.D., 29 North Street, Willimantic; Vice-chairman, Francis M. Dunn, M.D., 100 State Street, New London; Secretary-Treasurer, Max Climan, M.D., 242 Trumbull St., Hartford. Meetings twice annually in May and September.

DELAWARE

Affiliated with Philadelphia Roentgen Ray Society.

FLORIDA

Florida State Radiological Society.—President, Gerald Raap, M.D., 168 S. E. First St., Miami; Vice-president, H. O. Brown, M.D., 404 First Nat'l Bank Bldg., Tampa; Secretary-Treasurer, H. B. McEuen, M.D., 126 W. Adams St., Jacksonville.

GEORGIA

Georgia Radiological Society.—President, James J. Clark, M.D., Doctors Bldg., Atlanta; Vice-president, William F. Lake, M.D., Medical Arts Bldg., Atlanta; Secretary-Treasurer, Robert C. Pendergrass, M.D., Prather Clinic, Americus. Meetings twice annually, in November and at the annual meeting of the Medical Association of Georgia in the spring.

ILLINOIS

Chicago Roentgen Society.—President, David S. Beilin, M.D., 411 Garfield Ave.; Vice-president, Chester J. Challenger, M.D., 3117 Logan Blvd.; Secretary-Treasurer, Roe J. Maier, M.D., 7752 Halsted St. Meets second Thursday of each month, September to May, except December.

Illinois Radiological Society.—President, Ivan Brouse, M.D., 316 W. State, Jacksonville; Vice-president, Cesar Gianturco, M.D., Carle Hospital Clinic, Urbana; Secretary-Treasurer, Edmund P. Halley, M.D., 968 Citizens Bldg., Decatur. Meetings quarterly by announcement.

Illinois State Medical Society, Section of Radiology.—President, Roswell T. Pettit, M.D., 728 Columbus St., Ottawa; Secretary, Ralph G. Willy, M.D., 1138 N. Leavitt St., Chicago.

INDIANA

Indiana Roentgen Society.—President, J. N. Collins, M.D., 23 E. Ohio St., Indianapolis; President-elect, Stanley Clark, M.D., 108 N. Main St., South Bend; Vice-president, Juan Rodriguez, M.D., 2903 Fairfield Ave., Fort Wayne; Secretary-Treasurer, Clifford C. Taylor, M.D., 23 E. Ohio St., Indianapolis. Annual meeting in May.

IOWA

The Iowa X-ray Club.—Holds luncheon and business meeting during annual session of Iowa State Medical Society.

MAINE

See New England Roentgen Ray Society.

MARYLAND

Baltimore City Medical Society, Radiological Section.—Chairman, Marcus Ostro, M.D., 1810 Eutaw Place; Secretary, H. E. Wright, M.D., 101 W. Read St., Baltimore. Meetings second Tuesday of each month.

MASSACHUSETTS

See New England Roentgen Ray Society.

MICHIGAN

Detroit X-ray and Radium Society.—President, E. W. Hall, M.D., 10 Peterboro Street; Vice-president,

Sam W. Donaldson, M.D., 326 North Ingalls St., Ann Arbor; *Secretary-Treasurer*, E. R. Witwer, M.D., Harper Hospital. Meetings first Thursday of each month from October to May, inclusive, at Wayne County Medical Society Bldg.

Michigan Association of Roentgenologists.—*President*, E. R. Witwer, M.D., Harper Hospital, Detroit; *Vice-president*, D. W. Patterson, M.D., 622 Huron Street, Port Huron; *Secretary-Treasurer*, C. K. Hasley, M.D., 1429 David Whitney Bldg., Detroit.

MINNESOTA

Minnesota Radiological Society.—*President*, Walter H. Ude, M.D., 78 S. 9th St., Minneapolis; *Vice-president*, Leo G. Rigler, M.D., University Hospitals, Minneapolis; *Secretary-Treasurer*, Harry Weber, M.D., 102 Second Ave., S. W., Rochester. Meetings quarterly.

MISSOURI

The Kansas City Radiological Society.—*President*, L. G. Allen, M.D., 907 N. 7th St., Kansas City, Mo.; *Secretary*, Ira H. Lockwood, M.D., 306 E. 12th St., Kansas City, Mo. Meetings last Thursday of each month.

The St. Louis Society of Radiologists.—*President*, Joseph C. Peden, M.D., 634 N. Grand Blvd.; *Secretary*, W. K. Mueller, M.D., 607 N. Grand Blvd. Meetings fourth Wednesday of each month.

NEBRASKA

Nebraska Radiological Society.—*President*, E. W. Rowe, M.D., 128 N. 13th St., Lincoln; *Secretary*, D. Arnold Dowell, M.D., 117 S. 17th St., Omaha. Meetings first Wednesday of each month at 6 P.M. in Omaha or Lincoln.

NEW ENGLAND ROENTGEN RAY SOCIETY

(Maine, New Hampshire, Vermont, Massachusetts, and Rhode Island.) *President*, Frank E. Wheatley, M.D., 520 Beacon St., Boston; *Secretary*, E. C. Vogt, M.D., 300 Longwood Ave., Boston. Meetings third Friday of each month from October to May, inclusive, usually at Boston Medical Library.

NEW HAMPSHIRE

See New England Roentgen Ray Society.

NEW JERSEY

Radiological Society of New Jersey.—*President*, J. D. Tidaback, M.D., 382 Springfield, Summit; *Vice-president*, Milton Friedman, M.D., Newark Beth Israel Hospital, Newark; *Secretary*, P. S. Avery, M.D., 546 Central Ave., Bound Brook. Meetings at Atlantic City at time of State Medical Society, and Midwinter in Newark as called by president.

NEW YORK

Brooklyn Roentgen Society.—*President*, Albert Voltz, M.D., 115-120 Myrtle Avenue, Richmond Hill; *Vice-president*, A. I. L. Bell, M.D., Long Island College Hospital, Henry, Pacific, and Amity Sts., Brooklyn; *Secretary-Treasurer*, E. Mendelson, M.D.,

132 Parkside Ave., Brooklyn. Meetings first Tuesday in each month at place designated by president.

Buffalo Radiological Society.—*President*, John Barnes, M.D., 875 Lafayette Ave.; *Vice-president*, W. L. Mattick, M.D., 290 Highland Drive; *Secretary-Treasurer*, J. S. Gian-Franceschi, M.D., 610 Niagara Street. Meetings second Monday evening each month.

Central New York Roentgen-ray Society.—*President*, W. E. Achilles, M.D., 60 Seneca St., Geneva; *Vice-president*, M. T. Powers, M.D., 250 Genesee St., Utica; *Secretary-Treasurer*, Carlton F. Potter, M.D., 425 Waverly Ave., Syracuse. Meetings held in January, May, and October as called by Executive Committee.

Long Island Radiological Society.—*President*, David E. Ehrlich, M.D., 27 W. 86th St., New York City; *Vice-president*, H. Koiransky, M.D., 43-37 47th St., Long Island City; *Secretary*, S. Schenck, M.D., 115 Eastern Parkway, Brooklyn; *Treasurer*, Moses Goodman, M.D., 45-01 Skillman Ave., Long Island City. Meetings fourth Thursday evening each month at Kings County Medical Bldg.

New York Roentgen Society.—*President*, E. F. Merrill, M.D., 30 W. 59th St., New York City; *Vice-president*, I. W. Lewis, M.D.; *Secretary*, H. K. Taylor, M.D., 667 Madison Ave., New York City; *Treasurer*, R. D. Duckworth, M.D., 170 Maple Ave., White Plains. Meetings third Monday evening each month at Academy of Medicine.

Rochester Roentgen-ray Society.—*Chairman*, Joseph H. Green, M.D., 277 Alexander St.; *Secretary*, S. C. Davidson, M.D., 277 Alexander St. Meetings at convenience of committee.

Society of Radiological Economics of New York.—*President*, Albert L. Voltz, M.D., 115-120 Myrtle Ave., Richmond Hill; *Vice-president*, M. M. Pomeranz, M.D., 911 Park Ave., New York City; *Secretary*, W. F. Francis, M.D.; *Treasurer*, Theodore West, M.D., United Hospital, Port Chester. Meetings first Monday evening each month at McAlpin Hotel.

NORTH CAROLINA

Radiological Society of North Carolina.—*President*, Robert P. Noble, M.D., 127 W. Hargett St., Raleigh; *Vice-president*, A. L. Daughtridge, M.D., 144 Coast Line St., Rocky Mount; *Secretary-Treasurer*, Major I. Fleming, M.D., 404 Falls Road, Rocky Mount. Meetings with State meeting in May, and meeting in October.

OHIO

Cleveland Radiological Society.—*President*, North W. Shetter, M.D., Lakewood City Hospital, Lakewood; *Vice-president*, John Heberding, M.D., St. Eliza-

beth's Hospital, Youngstown; *Secretary-Treasurer*, Harry Hauser, M.D., Cleveland City Hospital, Cleveland. Meetings at 6:30 P.M. at Cleveland Chamber of Commerce Club on fourth Monday of each month from October to April, inclusive.

Radiological Society of the Academy of Medicine (Cincinnati Roentgenologists).—*President*, George Benzing, M.D., St. Elizabeth Hospital, Covington, Ky.; *Secretary-Treasurer*, Justin E. McCarthy, M.D., 707 Race St., Cincinnati, Ohio. Meetings held third Tuesday of each month.

PENNSYLVANIA

Pennsylvania Radiological Society.—*President*, Sydney J. Hawley, M.D., Geisinger Memorial Hospital, Danville; *First Vice-president*, William J. McGregor, M.D., 744 Franklin Ave., Wilkesburg; *Second Vice-president*, Oscar M. Weaver, M.D., 12 S. Main St., Lewistown; *Secretary-Treasurer*, Lloyd E. Wurster, M.D., 416 Pine St., Williamsport; *President-elect*, Charles S. Caldwell, M.D., 520 S. Aiken Ave., Pittsburgh. Annual meeting, May, 1938. Exact date and place to be decided.

Philadelphia Roentgen Ray Society.—*President*, Thomas P. Laughery, M.D., Germantown Hospital; *Vice-president*, Elwood E. Downs, M.D., Jeans Hospital, Fox Chase; *Secretary*, Barton H. Young, M.D., Temple University Hospital; *Treasurer*, R. Manges Smith, M.D., Jefferson Hospital. Meetings first Thursday of each month from October to May, Thompson Hall, College of Physicians, 19 S. 22nd St., 8:15 P.M.

The Pittsburgh Roentgen Society.—*President*, F. L. Schumacher, M.D., Jenkins Arcade; *Secretary*, H. N. Mawhinney, M.D., Mercy Hospital. Two Fall and two Spring meetings at time and place designated by president.

RHODE ISLAND

See New England Roentgen Ray Society.

SOUTH CAROLINA

South Carolina X-ray Society.—*President*, Robert B. Taft, M.D., 105 Rutledge Ave., Charleston; *Secretary-Treasurer*, Hillyer Rudisill, M.D., Roper Hospital, Charleston. Meetings in Charleston on first Thursday in November, also at time and place of South Carolina State Medical Association.

SOUTH DAKOTA

Meets with Minnesota Radiological Society.

TENNESSEE

Memphis Roentgen Club.—Chairmanship rotates monthly in alphabetical order. Meetings second Tuesday of each month at University Center.

Tennessee State Radiological Society.—*President*, H. S. Shoulders, M.D., 246 Doctors Bldg., Nashville; *Vice-president*, S. S. Marchbanks, M.D., 508 Medical Arts Bldg., Chattanooga; *Secretary-Treasurer*, Franklin B. Bogart, M.D., 311 Medical Arts Bldg., Chattanooga. Meeting annually with State Medical Society in April.

TEXAS

Texas Radiological Society.—*President*, R. G. Giles, M.D., Medical Arts Bldg., San Antonio; *President-elect*, Jerome H. Smith, M.D., Shannon West Texas Memorial Hospital, San Angelo; *First Vice-president*, C. F. Crain, M.D., 416 Chaparral St., Corpus Christi; *Second Vice-president*, M. H. Glover, M.D., 904 8th St., Wichita Falls; *Secretary-Treasurer*, G. D. Carlson, M.D., 3121 Bryan St., Dallas. Meets annually. San Antonio is next place of meeting.

VERMONT

See New England Roentgen Ray Society.

VIRGINIA

Radiological Society of Virginia.—*President*, Fred M. Hodges, M.D., 100 W. Franklin St., Richmond; *Vice-president*, L. F. Magruder, M.D., Raleigh and College Aves., Norfolk; *Secretary*, V. W. Archer, M.D., University of Virginia Hospital, Charlottesville.

WASHINGTON

Washington State Radiological Society.—*President*, H. E. Nichols, M.D., Stimson Bldg., Seattle; *Secretary*, T. T. Dawson, M.D., Fourth and Pike Bldg., Seattle. Meetings fourth Monday of each month at College Club.

WISCONSIN

Milwaukee Roentgen Ray Society.—*Secretary*, S. A. Morton, M.D., Columbia Hospital, Milwaukee. Meets monthly on first Friday.

Radiological Section of the Wisconsin State Medical Society.—*Secretary*, Russel F. Wilson, M.D., Beloit Municipal Hospital, Beloit. Two-day annual meeting in May and one day in connection with annual meeting of State Medical Society, in September.

University of Wisconsin Radiological Conference.—*Secretary*, E. A. Pohle, M.D., 1300 University Ave., Madison, Wis. Meets every Thursday from 4 to 5 P.M., Room 301, Service Memorial Institute.

EDITORIAL

LEON J. MENVILLE, M.D., *Editor*

HOWARD P. DOUB, M.D., *Associate Editor*

THE TEACHING OF RADIOLOGY IN SHORT COURSES

Medical science, ever-changing as it is, demands continuous education of its practitioners. The maintenance of a high standard of medical practice necessitates frequent visits to centers of learning by the average physician. The recognition of this fact in certain foreign countries has led to a system of post-graduate courses, which the physician, in characteristic fashion, is compelled to attend at stated intervals. In this country, adhering to our traditional and cherished attitude of *laissez-faire*, increasing opportunity for post-graduate education is being afforded without compulsion. Sponsored by the organized profession, the state, or the university, a large number of short courses on various subjects, ranging in length from a few days to several months, are being offered, particularly to the general practitioner. Some of these are of the "refresher" variety; others are devoted to newer advances. It should be clearly understood that this discussion does not concern itself with the longer, more formal courses of graduate training in the specialties.

Radiology, dynamic subject that it is, inevitably must occupy an important position in the post-graduate education of the general practitioner but the question of just what should be taught this same practitioner as to the use of the roentgen rays has never been adequately answered. Some reasonably consistent attitude must shortly be adopted in order to guide those who are being called upon, more and more frequently, to teach radiological subjects in short courses.

On this matter two opinions prevail. One contemplates the teaching of the indications for roentgen diagnosis and therapy with its possibilities and limitations, but would avoid the technics of roentgenology. In this program the practical methods of application of the roentgen rays, specifically such matters as the details of dosage or the description of roentgen diagnostic signs, would not be presented. The other program is more inclusive

and, with due regard to the limitations imposed by the lack of preparation of the student and the short period of time in which the subject must be covered, envisages an attempt to teach both phases of radiological knowledge.

No one will cavil at the presentation of the possibilities and limitations of radiology in refresher courses for general practitioners. It is hardly possible to disseminate too much knowledge of this subject among all physicians. But no such unanimity of opinion prevails as to the desirability of teaching the specific details of roentgenologic procedure in this fashion. The fear of turning out half-baked specialists, of encouraging the incompetent and dangerously unskilled application of such a potent weapon as the roentgen rays, has permeated all radiological teaching and especially that concerned with short courses. Such misgivings, doubtless, are not without foundation, yet they should be reconsidered. The time has come to face this problem squarely and to ask ourselves: Can too much medical education really be harmful? Is it not true that the more a rational individual learns of a subject, the more he appreciates his own limitations?

Extensive experience with post-graduate teaching indicates that the majority of physicians who register for courses in radiology are already practising roentgen diagnosis to some degree. In general they are the most progressive and conscientious practitioners in their community, but their situation in rural districts, where specialists in roentgenology are not available, makes this practice imperative. Any teaching which will improve the technic and diagnostic ability of these physicians is all to the good. That some practitioners who are not already "operating" an x-ray machine and have no real necessity for engaging in roentgen diagnosis may be induced to do so by the small knowledge gained in a short course is a possibility. It is more probable, however, that the imprudent

physician will enter into whatever practice his fancy or his apparent necessities direct him, regardless of his qualifications. Emphasis in the short course must be placed primarily upon the broader aspects of radiology as applied to medical practice but attention should also be given to technic and method. The exercise of reasonable discretion in the choice and presentation of these subjects will tend to improve medical practice with very little possibility of coincident harmful results.

LEO G. RIGLER, M.D.

ANNOUNCEMENT

SCIENTIFIC EVENT

The Third International Cancer Congress, under the auspices of the International Union against Cancer, will be held in the United States, September 11 to 16, 1939, at the Hadson Hall Hotel, Atlantic City, N. J.

The president of the Congress is Professor Francis Carter Wood, M.D., Director of the Institute of Cancer Research of Columbia University, New York City; Donald S. Childs, M.D., of Syracuse, N. Y., is Secretary-Treasurer, and A. L. Loomis Bell, M.D., of Long Island College Hospital, Brooklyn, N. Y., is in charge of transportation and exhibits.

The proposed sections are as follows: General research; biophysics; genetics; general pathology of cancer; surgery of cancer; radiological diagnosis of cancer; radiotherapy of cancer; statistics, and education. Further details concerning section chairmen, committees, and other data will be announced later.

The membership fee will be \$15. All inquiries should be addressed to the Institute of Cancer Research, 1145 Amsterdam Avenue, New York City.

BOOKS RECEIVED

Books received are acknowledged under this heading, and such notice may be regarded as an acknowledgment of the courtesy of the sender. Reviews will be published in the interest of our readers and as space permits.

CLINICAL OUTLINE OF PHYSIOTHERAPY: Rational Treatment of Chronic Maladies. By A. JOSEPH RIVIERE, Doctor of Medicine of the Faculty of Paris, D.S.C. (*honoris-causa*), of the Lincoln Memorial University, U. S. A.; Editor-in-chief of "Annals of Physiotherapy," Gold Medal from the National and

International Expositions of Medicine. Medical Edition. A volume of 300 pages. Published by Norbert Maloine, 27 Rue de l'École de Médecine, Paris, 1932. Price: (not known).

RADIOPHYSIOLOGY AND RADIOTHERAPY: Review of Biological Studies, Technics, and Therapeutics. Published by CL. REGAUD, Director; A. LACASAGNE, Associate Director, and R. FERROUZ, Chief Physicist of the Laboratory of Radiophysiology of the Radium Institute (Archives of the Radium Institute of the University of Paris and the Curie Foundation). A volume of 188 pages. Issued by Les Presses Universitaires de France, March, 1937. Price: 50 fr.

POST-OPERATIVE RADIOLOGICAL EXAMINATION OF THE COMMON BILE DUCT. By B. DESPLAS, P. MOULONGUET, and P. MALGRAS. A volume of 120 pages, with 40 figures. Published by Masson et Cie, Paris, 1938. Price: 40 fr.

PHYSIOTHERAPY, ORGANIZATION FOR WORLD PEACE: Souvenirs, Documents. By A. JOSEPH RIVIERE. The conceptions, the works, the facts, the acts, and dates. Published by Imprimerie et Librairie Centrales Société, Rue Bergère 20, Paris, 1937. Price: (not known).

INJURIES OF THE FOOT AND X-RAYS: Malleoli, Astragalus, Calcis, the Fore-foot. By ETIENNE DESTOT. Preface by DR. ALEXIS CARREL. Second Edition. A volume of 292 pages, with 156 figures. Published by Masson et Cie, Paris, 1937. Price: 45 fr.

BOOK REVIEWS

OUTLINE OF RADIOLOGY. Prepared and published by the Educational Committee of the Pennsylvania Radiological Society: Sidney J. Hawley, M.D., *Chairman*, John T. Farrell, Jr., M.D., Harold W. Jacox, M.D., Zoe A. Johnston, M.D., Forrest L. Schumacher, M.D., James J. Quiney, M.D., and James L. Weatherwax, M.A., 1937. A litho-printed and paper bound volume of 126 pages. Price: \$3.00. (Order from Sidney J. Hawley, M.D., Geisinger Memorial Hospital, Danville, Pennsylvania.)

This Outline was prepared by the Educational Committee of the Pennsylvania Radiological Society to complement a systematic review of radiology which was started by that Society in May, 1936. This Outline is not intended to be a textbook of radiology, but rather a guide for study. The Committee has outlined the more important conditions in such a way that a physician studying the subject will have a guide and readily available bibliography of the more important articles concerning each

subject. The student is expected to read those articles which will supplement and add to his knowledge and it is hoped that the references quoted will be read more than the outline itself.

The Outline contains 51 subjects which in a general way can be summarized as relating to the following topics: Diseases of Bones and Joints, Brain, Mastoids, Sinuses, Teeth, Larynx, Chest and Heart, Gastro-intestinal Tract, Gall Bladder, Pyelography, Localization of Foreign Bodies, Physics of Radiation and Radium Therapy, Biological Effects of Irradiation, Typical Therapy Technics, Factors to be Considered in the Treatment of Tumors, Records for Radiation Therapy, Metastasis, and a detailed bibliography relating to the therapy of certain specific conditions.

The general scheme of the Outline is most excellent and, as far as possible, the various subjects are discussed in the following order: Definition, cause, gross morbid anatomy and physiology, roentgen-ray appearance, differential diagnosis, and treatment. Subjects which do not lend themselves to such a consideration are outlined in an equally efficient manner.

The Pennsylvania Radiological Society are to be complimented for sponsoring this practical and concise outline of study which should be very helpful to students of radiology and to those who are interested in a refresher course concerning the subject.

LEHRBUCH DER RÖNTGENOLOGISCHEN DIFFERENTIALDIAGNOSTIK DER ERKRANKUNGEN DER BAUCHORGANE (Textbook of Roentgenologic Differential Diagnosis of Diseases of the Abdominal Organs). By Dr. Med. Habil. WERNER TESCHENDORF, Chefartz des Strahleninstituts der Allgemeinen Ortskrankenkasse Köln. A textbook of 477 pages containing 929 illustrations. Published by Georg Thieme, Leipzig, 1937. Price: 33 RM. (in the U. S.) bound.

This unique textbook by an outstanding German radiologist should be very popular with those physicians fortunate enough to read the German language. The author has discussed in a very comprehensive and informative manner all the details entering into the roentgenographic differential diagnosis of abdominal disease. The marginal notes in small type which connote the subject discussed in the contiguous text are a very useful innovation and facilitate a rapid perusal of the contents when searching for specific conditions

The volume consists of eight chapters which are captioned as follows: Chapt. 1, The Stomach; Chapt. 2, The Operated Stomach; Chapt. 3, The Duodenum; Chapt. 4, The Biliary Tract; Chapt. 5, The Small Intestine; Chapt. 6, The Large Intestine; Chapt. 7, Kidney, Ureters, Bladder, and Prostate; Chapt. 8, Artificial Pneumoperitoneum as Concerns the Liver, Pancreas, Spleen, and Abdominal Tumors.

The chapters concerning the gastro-intestinal tract, particularly those relating to the stomach and duodenum, are unusually well presented. Throughout the text frequent reference is made to the literature, both foreign and American, and as a rule the significant references have been included. The consideration of cholecystography (16 pages) seems somewhat brief considering the importance of the subject; however, the pertinent facts have been covered in a very practical manner. The subjects of terminal ileitis and related conditions are touched on rather briefly and American readers will feel that this consideration of the subject is inadequate.

The author, who is personally interested in the technic of artificial pneumoperitoneum, presents some excellent illustrations portraying the value of this method of examination. The interest of American radiologists in this procedure has lagged in recent years but, considering the excellent results achieved by the author with this type of examination, a reconsideration of its usefulness in certain abdominal conditions would seem justified.

The general excellence of the illustrations is deserving of special commendation and these, together with the general typography, are a tribute to the publisher whose reputation for quality work is well known.

RÖNTGENDIAGNOSTIK DER KNOCHEN- UND GELLENKRANKHEITEN (Roentgen Diagnosis of Diseases of Bones and Joints). by Professor Dr. ROBERT KIENBÖCK, Vienna. Volume I, Differential Diagnosis of Neoplastic Diseases of Bone. A volume of 104 pages, with 26 figures. Published by Urban & Schwarzenberg, Berlin and Vienna, 1933. Price: RM. 8.50.

In this book Professor Kienböck, one of the greatest European radiologists, discusses tumorous diseases of bone, a subject in which he is recognized as an international authority. The various lesions are taken up in detail and con-

sidered from both the roentgenologic and the clinical points of view and interesting or illustrative roentgenograms are introduced to supplement the text. Kienböck often introduces new terms which have little superiority over the older, commoner ones, and in many instances they confuse the reader. The booklet is of interest primarily to roentgenologists and orthopedists, and to students wishing to become as well grounded as possible in this very confusing field.

THEORETICAL PRINCIPLES OF ROENTGEN THERAPY. Edited by ERNST A. POHLE, M.D., Ph.D., F.A.C.R., Professor of Radiology, Chairman, Dept. of Radiology and Physical Therapy, University of Wisconsin. Contributors: R. R. Newell, M.D., Professor of Medicine (Radiology), Stanford University Medical School; K. Wilhelm Stenstrom, Ph.D., Professor of Biophysics, University of Minnesota Medical School; Ernst A. Pohle, M.D., Ph.D.; Lauriston S. Taylor, Ph.D., Physicist, Bureau of Standards, Washington, D. C.; Francis Carter Wood, M.D., Director, Institute of Cancer Research, Columbia University. Foreword by W. Edward Chamberlain, B.S., M.D., F.A.C.R., Professor of Radiology, Temple University School of Medicine, Philadelphia. A volume of 272 pages, with 132 illustrations. Published by Lea & Febiger, Philadelphia, 1938. Price: \$4.50.

In this book, which is dedicated to the memory of his former Chief, the late Preston M. Hickey, Pohle has collected and edited a series of chapters by recognized authorities on the theoretical foundations of roentgen therapy. In a brief foreword, Chamberlain points out the close linkage between physicist and physician in this ever-expanding field to the mutual advantage of both. Stenstrom's chapter on the physics of roentgen rays (pages 17-59) boils down to the essential facts: the structure of the atom, the properties and nature of cathode rays, roentgen rays, their properties and quantitative and qualitative measurements, and treats the material from a descriptive rather than a mathematical point of view. Newell (pages 61-115) takes up roentgen-ray apparatus, with special reference to the up-to-date developments, including supervoltage and artificial radio-activity. Notwithstanding the complexity of the subject, Newell's presentation is in all essentials complete, and in addition is replete with sane, conservative observations. One may be quoted: "Patients will

inevitably assume that if 200 kv. will almost cure cancer, surely 1,000,000 v. will cure it easily. That is a proposition which will take a deal of proving! We will be wise to look carefully at the experience of the places now using supervoltage before we set up these costly installations everywhere. The advertising value of even 500,000 v., however, is bound to prove enormously tempting. Will patients and their physicians have the wisdom to inquire, not 'how many volts?' but 'what is the training and experience of the radiologist?'" Taylor and Pohle collaborate on the chapter on dosimetry (pages 121-178). They discuss units of quality and quantity and describe apparatus for their measurements. The determination of the "clinical dose" is treated at due length and with suitable detail. Various methods of treatment are sketched. The importance of adequate records is illustrated by samples. Wood (pages 188-227) discusses the biologic foundations of roentgen therapy, a subject of the greatest clinical importance. He considers the underlying physical foundations of the radiation effect and the action of radiation on normal and pathologic cells, and exemplifies them with excellent illustrations. The final chapter on protection by Taylor (pages 233-260) takes up protection against direct and scattered radiations and materials for this purpose. The recommendations of the Advisory Committee on X-ray and Radium Protection are given *verbatim*.

The arrangement of the book is excellent and the illustrations are well chosen and well reproduced. The bibliography is adequate.

Pohle's aim is to serve two groups of readers: the radiologist, who must have a thorough understanding of the theoretical principles underlying roentgen therapy, and the research worker, who is not interested in the clinical application of roentgen rays.

In my opinion Pohle's aim was so good that he has hit the center of the bull's eye.

In spite of considerable thought I can offer no destructive criticism of any part of the book. I know no place else where one can find so much important material in so small a space. To all interested in roentgen therapy the book can be recommended without reservations.

RÖNTGENDIAGNOSTIK DER KNOCHEN UND GELENKKRANKHEITEN (Roentgen Diagnosis of Bone and Joint Diseases). Volume IV, Degenerative Diseases of the Vertebrae.

By Professor ROBERT KIENBÖCK, Vienna. A volume of 450 pages, with 215 illustrations. Published by Urban & Schwarzenberg, Berlin, 1936. Price: RM. 24.00.

This volume deals with those conditions which the author calls degenerative diseases of the vertebrae and which he has classified as follows:

1. Scheuermann's adolescent kyphosis.
2. Deforming spondylarthrosis.
3. Osteoporotic kyphosis.

These subjects are each discussed as to etiology, diagnosis, and roentgenographic appearance and followed by various case reports together with their related roentgenograms.

In the group of cases under the heading "deforming spondylarthrosis" are various lesions such as hematoma of the vertebrae producing secondary changes, but for the most part the author feels that these degenerative changes are secondary to adolescent kyphosis.

The author has presented a diagnostic atlas of these conditions obviously for use mainly by roentgenologists and those interested in the roentgenologic appearance of these lesions. Nearly every variation one may find in these conditions is presented. Whether one agrees with the diagnostic findings in all cases does not matter so much, as the material on each case is well presented and one may draw his own conclusions.

The illustrations are for the most part good though in many instances are not as clear as one would desire in such an atlas of roentgenology. The bibliography is quite complete. The volume is a very useful one for reference though by itself it covers a small part of the subject of x-ray diagnosis of conditions of bones and joints.

RADIOTHERAPIE GYNECOLOGIQUE (Gynecologic Radiotherapy), CURIE- ET RÖNTGENTHERAPIE (Radium and Roentgen Therapy). By R. MATHEY-CORNAT, Radiologiste de Hôpitaux, Médecin de la Fondation Bergonie (Centre anticancereux de Bordeaux et du Sud Ouest), Chef du Service central d'Electroradiologie des Hôpitaux du Groupe Pellegrin-Le Tondou. A volume of 309 pages, with 84 illustrations. Published by Masson et Cie, Paris, 1936. Price: 60 francs.

This book intends to present to radiologists, general men, surgeons, and gynecologists the

essential facts in regard to gynecologic radiotherapy and at the same time to give them up-to-date information on the progress that is being made in this very important branch of the therapy of diseases of the female genital tract. To this end the author has eliminated non-essential and theoretic conceptions and has made the subject matter primarily clinical.

The book opens with a section on the fundamentals of gynecologic radiotherapeutic technique. There follows a chapter on benign lesions of the female genitalia. The third chapter is about disturbances of the endocrine glands and menstrual disorders. There then follow chapters on various gynecologic diseases with special emphasis laid on malignant tumors. Like many European authors, Mathey-Cornat includes carcinoma of the breast. The author cites 563 references in his bibliography and closes with an extensive index. The whole makeup of the book is excellent. Any physician who wishes to be conversant with gynecologic radiotherapy may well read this book with interest and profit.

CUTANEOUS CANCER AND PRECANCER. A practical monograph, by G. M. MACKEE, M.D., Professor of Clinical Dermatology and Syphilology and Director of Skin and Cancer Unit, New York Post-graduate Medical School and Hospital, Columbia University, and ANTHONY C. CIPOLLARO, M.D., Associate in Dermatology, Skin and Cancer Unit, New York Post-graduate Medical School and Hospital, Columbia University, with a Foreword by FRANCIS CARTER WOOD, M.D. A volume of 222 pages, with 245 illustrations. Published by The American Journal of Cancer, New York, 1937. Price: \$3.75.

This practical monograph on cutaneous cancer and precancerous dermatoses is divided into four chapters. The first chapter, very brief, deals with the morbidity and mortality of cutaneous cancer. The second chapter deals with precancerous dermatoses, covering some ninety pages. The third chapter deals with cutaneous malignancies, dividing them into two main groups, carcinoma and sarcoma, covering about ninety pages. The third chapter, as well as the second, has a rather extensive bibliography. The fourth chapter contains a survey of the established therapeutic methods. It covers briefly the surgical, chemical, and physical means of therapeutics.

The subject matter is concise and conveni-

ently arranged, and offers an excellent résumé of the subjects of cutaneous cancer and precancerous dermatoses. Each pathological condition is discussed from the clinical standpoint, anatomical and histopathological illustrations are presented, and therapeutic suggestions are made.

The book is extremely valuable for its numerous anatomical and histopathological illustrations, and its able presentation. This monograph should be of interest particularly to the dermatologist and therapeutic radiologist

GASTROSCOPY: THE ENDOSCOPIC STUDY OF GASTRIC PATHOLOGY. By RUDOLPH SCHINDLER, M.D., Associate Clinical Professor of Medicine, University of Chicago, Attending Gastroscopist, Michael Reese Hospital, Consulting Gastroscopist, Cook County Hospital, Chicago. A volume of 343 pages, with 89 text illustrations and 97 color reproductions. Published by The University of Chicago Press, Chicago, 1937. Price: \$7.50.

According to the author, the exact anatomic diagnosis of gastric disease became possible with the introduction of two morphologic methods—roentgenology and gastroscopy. Although gastroscopy is older, its perfection has been more recent. The purpose of this book is to demonstrate that gastroscopy is similarly indispensable in the diagnosis and treatment of gastric disease. Whether or not one agrees entirely with the author's opinion, it cannot be denied that he knows his subject and has presented it in a most comprehensive and understandable manner. Roentgenologists will do well to study this text, not with the idea of hoping to master the method, but in order to better realize some of the deficiencies of their own method of examination, and the limitations of the procedure under discussion.

In a discussion of some of the optical problems of gastroscopy the author emphasizes that "negative findings in gastroscopy do not exclude the presence of a pathologic lesion, because it is not possible to be certain in each case that all of the gastric wall has been seen. The flexible gastroscope has lessened some of these difficulties but it is impossible, even in the most favorable case, to be sure that one has seen every small lesion." This is due to the fact that mechanical and optical limitations create certain blind spots the extent of which may vary in individual cases. The antrum, angu-

lus, and pylorus are seen with the flexible gastroscope in about 90 per cent of all cases. The pylorus can almost always be observed by a skillful gastroscopist although the lesser curvature of the antrum often remains hidden from view. The lower pole of the stomach always contains a sector which is not seen because the objective looks sideward. Lesions of the cardia are best seen with the esophagoscope and should form a contra-indication to the use of the gastroscope. That part of the cardia which is immediately adjacent to the objective, especially at the side of the lesser curvature, cannot be seen even with retrograde systems.

The technic of gastroscopy is discussed in great detail and definite contra-indications emphasized. Under indications for the procedure the author states that gastroscopy should be a routine method of the gastroenterologist. This is probably an idealistic attitude because if gastroenterologists have the same difficulty in mastering the procedure as many have had in becoming proficient in roentgenologic procedures, the examination will have little dependable value as a routine except in the hands of experts.

The chapters relating to ulcers, gastritis, and tumors are particularly informative and bespeak the wide experience and keen observation of the author.

Roentgenologists will be especially interested in the chapter concerning the relationship between gastroscopy and x-ray. In the minds of expert examiners some variances of opinion will be incited. The subject is rightfully summarized, however, by the statement, "Gastroscopy and x-ray, when used together are not mutually exclusive, but on the contrary, should be used together."

The author has written a classic text concerning a procedure which bids fair to influence the diagnosis and treatment of many cases of gastric disease. Some parts are colored by the enthusiasm of an active pioneer but others reveal a frank conservatism that is commendable. It should be read and studied by all concerned with the diagnosis and treatment of gastric disorders.

CLINICAL ROENTGENOLOGY OF THE CARDIOVASCULAR SYSTEM: ANATOMY, PHYSIOLOGY, PATHOLOGY, EXPERIMENTS AND CLINICAL APPLICATIONS. By HUGO ROESLER, M.D.,

Associate Professor of Roentgenology and Cardiologist, Department of Medicine, Temple University School of Medicine; Cardiologist, Temple University Hospital; Consulting Cardiologist, Shriner's Hospital for Crippled Children, Philadelphia. A volume of 343 pages containing 198 illustrations. Published by Charles C. Thomas, Springfield, Illinois, 1937. Price: \$7.50.

For many years the American literature has suffered for want of a comprehensive text concerning roentgenology of the cardiovascular system and it is doubtful if this method of examination has been adequately appreciated by the average clinician and roentgenologist in this country. Roesler, because of his ability as a cardiologist and a keen radiologist, has presented the subject in a manner that could be approached by few other authors. The arrangement of the text is excellent and the order of presentation, beginning with the fundamentals of the subject and working up to the clinical applications, bespeaks the experience of a good teacher. Because of the detailed manner in which the subject has been considered the text cannot be read with rapidity. The slower and more patient "small dose" method of study was found more practical.

This excellent text, together with its voluminous bibliography, will unquestionably remain as a fundamental work concerning roentgenology of the cardiovascular system for some time to come. It is recommended without reservation for roentgenologists, clinicians, and students.

RADIOLOGICA (International Journal of Photobiology and Biophysics, Medical Radiology and Photochemistry). Edited by H. JAUSION, Paris, J. PLOTNIKOW, Zagreb, H. SCHREIBER, Berlin. Published by Walter de Gruyter & Company, Berlin W35, Woyrschstrasse 13, Germany. Price: 35 R.M. per volume less 25 per cent outside of Germany.

This is a new journal scheduled to appear as three volumes annually, each volume to consist of six pamphlets (about 18 pages). It is the purpose of this new publication to summarize in review form original contributions pertaining to photobiology, biophysics, medical radiology, and photochemistry. The original articles will appear in French, German, English, or Italian. A summary of each article will be printed in English, German, and French. There will also be a section con-

taining a summary of all important work in the literature. Contributors will be reimbursed at the rate of 30 R.M. for each printed page and manuscripts should be sent to the Chief Editor, Doctor Hans Schreiber, Berlin-Friedenau, Cecilengärten 45, Germany. In the next volume 32 papers will appear. A sample copy of this journal contains articles on the following subjects:

Heliotherapy of Lupus Tuberculosis (French);
A Radiometric Method of Measuring Ultra-violet Solar Radiation Intensities in the Stratosphere (English);
Biologic Significance of Reflected Ultra-violet Rays (German);
Physicochemical Studies on *Melanins* (English);
Spectrographic Researches Concerning Irradiated Substances (Italian);
Roentgen Therapy with High Voltage (French);
The Absorption of Short Wave Energy in Biological Tissues (German);
Activation by Light of the Immunizing Function of the Skin (French).

DIATHERMY. Third Edition. By ELKIN P. CUMBERBATCH, M.A., B.M. (Oxon.), D.M. R.E. (Camb.), F.R.C.P., Medical Officer in Charge of Electrical Department and Lecturer on Medical Electricity, St. Bartholomew's Hospital. A volume of 560 pages, with 168 illustrations. Published by William Wood & Company, Baltimore, Maryland, 1937. Price: \$6.00.

The author, in collaboration with nine workers in special fields, has written a third edition on the subject of medical and surgical diathermy. The rapid advance in knowledge of diathermy and the progress that has been made in medical and surgical uses of high frequency currents have rendered it necessary to compile this new and enlarged volume on the subject.

The book is divided into three parts, the first of which is concerned with the evolution of diathermy and the physical principles underlying the production of high frequency currents. The second and third parts cover the subjects of medical and surgical diathermy, respectively.

The author has selected and described in detail several machines required for various types of treatment, and has discussed each method of treatment. Rather brief chapters are included regarding treatment by ultra-short waves and by induction cables. It is apparent that the conventional type of diathermy is still the most

popular in the British Isles. The book may be criticized in that the experiments described have been inadequately controlled. For a topic that is highly technical, the book is written in a readable style.

This book can be recommended to any physician who desires information concerning conventional diathermy. The discussion on the newer short wave diathermy is, however, very limited.

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ANIMAL EXPERIMENTATION

The Behavior of the Reticulocytes of the White Mouse after Roentgen Therapy. H. Langendorff. *Strahlentherapie*, 1937, **59**, 652.

The author continued his studies dealing with the effect of roentgen rays on the reticulocytes of mice. Technic: 180 kv., 4 ma., 30 cm. F.S.D., $HVL_{Cu} = 0.85$ mm.; exposure of from 1 to 9 minutes. The doses applied and the intervals between treatments were varied. It appeared that the degree of radiation effect following simple fractionated doses of roentgen rays does not only depend on the total dose but also on the amount and order of each single dose, as well as on the spacing. The maximum effect was observed if each following exposure was given at the height of the reaction from the previous treatment. This manifested itself in a constant increase of the number of reticulocytes.

ERNST A. POHLE, M.D., Ph.D.

Microcinematographic Studies of the Effect of Roentgen Rays on Normal and Tumor Cells in Tissue Cultures. H. Vollmar and B. Rajewsky. *Strahlentherapie*, 1937, **60**, 524.

The authors exposed cultures of normal (chicken embryo) and pathological tissue (mouse carcinoma) to roentgen rays. Technic: 21 kv., 30 ma., 16 r/min., 480-2,880 r total dose. Some of the microscopic observations were recorded by a motion picture film. It appeared that the single cells constituting a cell complex showed very different reactions to irradiation. This expressed itself in the reaction speed as well as in the type of injury following exposure: photomicrograms are appended demonstrating this observation. Studies of the growth of an irradiated culture during irradiation itself seemed to point to a primary localized effect of irradiation. The authors could also prove experimentally the fact that while certain cells in a cell complex were markedly injured others escaped injury entirely.

ERNST A. POHLE, M.D., Ph.D.

The Action of Marconi-therapy on Experimental Peritonitis from *B. coli*. Leopoldo Giacobbi. *Archivio di Radiologia*, 1937, **15**, 220-225.

Rabbits in which peritonitis had been produced were treated with short wave diathermy. It was found that the treated animals lived longer than the controls, but no histologic changes could be found in them.

E. T. LEDDY, M.D.

ARTHRITIS

Non-traumatic Protrusion of the Acetabulum. A. Mayoral. *Southern Med. Jour.*, December, 1937, **30**, 1163-1165.

A case of Otto's pelvis is reported, developing in two years' time following a low grade arthritis of the hip.

The patient was a man, bed-ridden, and the lesion was in the hip joint of a leg which had been amputated at the thigh. The author concludes that infection and muscle action play an important rôle in the development of this condition.

JOHN M. MILES, M.D.

BLOOD CHANGES

The Effect of Roentgen Rays on Erythropoiesis. K. Mardersteig. *Strahlentherapie*, 1937, **59**, 609.

The author studied the influence of roentgen radiation given in therapeutic doses on the reticulocytes of human blood. His conclusions are based on observations made in 13 patients with carcinoma of the bronchus, one with carcinoma of the esophagus, two with carcinoma of the liver, six with carcinoma of the stomach, six with metastatic bone carcinoma, six with myelocytic leukemia, and five cases with lymphocytic leukemia. The customary deep therapy technic was used and applied according to the method of Holfelder. It appeared that following a temporary stimulation a definite inhibition of the erythropoietic function occurred and was balanced by regeneration from the bone marrow. In patients in whom the bone marrow function has been disturbed by the malignant disease this regeneration is either insignificant or does not take place at all. If bone marrow regeneration is noted at the beginning of the treatment, the prognosis is usually poor. The same holds true if the reticulocytes are incurred before irradiation, indicating a hyperfunction of the red bone marrow. The determination of the reticulocytes was of no prognostic value in the irradiated cases of myelocytic leukemia. However, in patients with lymphocytic leukemia who responded well to irradiation the erythropoietic function was increased.

ERNST A. POHLE, M.D., Ph.D.

BONES (DISEASES)

Paget's Disease with Unusual Findings. Giuseppe Bonifazi. *Archivio di Radiologia*, 1937, **15**, 217-219.

The author reports a case of Paget's disease in which the diagnosis was possible only by roentgenogram, which he reproduces. The patient, a woman of 52, had had pain and lameness in the hip and back for eight years, with a negative examination except as above cited.

E. T. LEDDY, M.D.

BREAST CANCER

Gingival Metastasis from Cancer of the Breast. M. Lüdin. *Strahlentherapie*, 1937, **60**, 304.

The author reports a very unusual case of a gingival metastasis originating from a primary carcinoma in the breast. The patient first noticed a loosening of the last left lower molar and then, in the surrounding gingiva,

discovered a strawberry-colored growth with irregular surface which bled easily. Biopsy revealed an adenocarcinoma. Roentgen therapy was applied to the lesion directly and also through the outer skin. Technic: 180 kv., 4 ma., 0.5 mm. Cu + 1 mm. Al, 230 r per sitting, total dose 2,300 r. The tumor responded well to irradiation and at the end of an observation period of 15 months had not yet recurred.

ERNST A. POHLE, M.D., Ph.D.

CANCER (THERAPY)

Complete Destruction of a Humerus by Osteoclastic Carcinomatous Metastases. R. Finsterbusch and G. Schumann. *Röntgenpraxis*, May, 1937, 9, 318-323.

The course of an extensive destruction of a metastasis from a primary cancer of the breast to a humerus is shown. The humerus was completely destroyed and no evidence of bone structure could be seen on roentgenograms. There occurred a marked shortening of the soft tissues of the arm. X-ray therapy achieved a worthwhile palliation.

HANS W. HEFKE, M.D.

DOSAGE

Present Status of the Definition and the Measurement of the Dose. H. Holthusen. *Strahlentherapie*, 1937, 59, 563.

This is the text of an address given by Holthusen in memory of Albers-Schönberg. He reviews briefly the present status of dosimetry, touching the problems of back-scatter, direct and indirect determination of the applied dose, and the relation between the measured dose and effect in the tissue.

ERNST A. POHLE, M.D., Ph.D.

Distribution of Roentgen-ray Intensity during Irradiation with Convergent Beams. M. Nakaidzumi and N. Motida. *Strahlentherapie*, 1937, 60, 307.

The authors used a small ionization chamber for the determination of the intensity distribution of roentgen rays in a wax phantom when using multiple convergent beams. The isodose curves have an entirely different shape under these conditions as compared with the standard curves available for single fields. The depth dose with convergent beams is much higher—up to 6 cm. below the surface—as compared with the single-field method. The periodical distribution of the dose during a single irradiation with convergent fields varies with the depth dose and with the distance from the central axis.

ERNST A. POHLE, M.D., Ph.D.

The Absorption and Scattering of Monochromatic Roentgen Rays in Water, Triolein, Blood, Skeletal

Muscle, and Subcutaneous Tissue of Man. H. Trübsenstein. *Strahlentherapie*, 1937, 60, 330.

The author determined the mass absorption coefficients of the various media named, using monochromatic roentgen rays between 0.128 and 1.433 Å. produced by means of the "filter difference" method developed by Küstner. Muscle tissue absorbs for all wave lengths the same as water; longer wave lengths are absorbed more in blood and somewhat less in subcutaneous tissue with a higher water content than water. Triolein (an oil) and subcutaneous tissue with low water content absorbed less than water and approached the same values as human fat. For radiation of short wave length the mass absorption coefficients of all examined materials are nearly equal. For practical purposes one must realize, therefore, that depth doses obtained in a water phantom hold for subcutaneous tissue with a high water content if superficial radiation therapy is given. For subcutaneous tissue with a low water content the depth dose in 6 cm. may be 80 per cent higher than the one determined in the water phantom. For deep therapy using roentgen rays of short wave length the water phantom is well suited for determining isodose curves.

ERNST A. POHLE, M.D., Ph.D.

EPILEPSY

Some Factors in the Pathogenesis of Genuine Epilepsy as Determined Radiologically. Eugenio Fischel. *Archivio di Radiologia*, September-December, 1936, 15, 329-335.

Fischel points out that in epilepsy there is usually an enlargement of the sella, and as a result of this there is an upset in the endocrinal balance of the pituitary, causing epilepsy by a transitory ischemia. The underlying lesion is probably an inflammatory one.

E. T. LEDDY, M.D.

FLUOROSCOPY

Testing the Ability to See in the Dark. Chantaine and Cramer. *Röntgenpraxis*, May, 1937, 9, 329-336.

There is still some dispute about the comparative value of fluoroscopy and films of the chest. It may be possible that some roentgenologists have a peculiarly acute vision in the darkroom, which may be very poor in others. The authors attempted to test 30 physicians and 20 patients for their ability to see in the darkroom. They did it by using roentgenograms of lead numbers of different contrast; the lead numbers were exposed to 10, 12, 14, etc., per cent up to 20 per cent of the routine exposure. The films showing these differently exposed numbers were then read in front of the fluoroscopic screen under the normal conditions of fluoroscopy. The person to be examined was asked to read the numbers after two, five, and ten minutes of adaptation to the dark. Three different grades of visual accuracy were arranged; good, medium, and

poor. After two minutes of adaptation one-third of the persons examined were insufficiently adapted and could not see any numbers; only four had become adapted to the best possible degree after two minutes. All others needed ten minutes. There are persons who show a fast adaptation and a very acute vision in the dark, but others show slow adaptation and very poor vision, even after ten minutes.

Only six of 30 physicians passed the test as good: 10 had a medium grade and 14 a poor one. Only about one-fifth of the examined persons had good vision in the dark, one-third medium, and one-half poor.

The authors conclude that it would be advisable to test in the dark the visual acumen of physicians who are supposed to do chest fluoroscopy, especially when fluoroscopy is used as the only roentgen examination of the chest.

HANS W. HEFKE, M.D.

FRACTURES

Contribution on Traumatic Epiphyseal Separation of the Distal End of the Leg. C. F. Giegy. Schweiz. med. Wchnschr., July 10, 1937, 67, 626, 627.

The author reports the results of follow-up of ten separations of the tibial epiphysis and seven of the fibular, of which fourteen and six, respectively, were followed. The injuries were divided into two classes: abduction-pronation separations, with a wide medial separation in the tibia, a small chip fracture laterally (two cases), and a supra-malleolar fibular fracture; and adduction-supination separation, with slight separation of the tibial epiphysis, more marked of the fibular, and sometimes in adults a fracture of the medial malleolus.

Treatment consisted of reduction and immobilization in U-splints or plaster for from five to six weeks. Excellent functional results were obtained in all cases.

L. G. JACOBS, M.D.

GASTRO-INTESTINAL TRACT (DIAGNOSIS)

The Stimulative Action of Other Parts of the Gastro-intestinal Tract on the Colon. Demetrio Messuti. Archivio di Radiologia, 1937, 15, 198-216.

The author studied roentgenologically the stimulative action exercised on the colon by the stomach and small intestine both after fasting and after food. He found that the digestive processes in the colon were all accelerated after the entrance of food higher up in the alimentary canal.

E. T. LEDDY, M.D.

The Relative Importance of Food Idiosyncrasy in Gastro-intestinal Diseases. William C. Chaney. Southern Med. Jour., December, 1937, 30, 1185-1188.

Gastro-intestinal allergy, a true tissue hypersensitivity to certain foods, occurs more frequently than is generally thought. The history, trial diets, skin tests,

search for eosinophils in the stool and nasal secretions, and the x-ray constitute diagnostic approaches.

The x-ray findings are not characteristic of the condition, but help exclude organic pathology. The author urges a modified Graham-Cole examination with the fat meal consisting of cream, eggs, wheat bread, and hot chocolate. These four foods are those which most frequently produce allergic reactions. If, after this meal, the patient develops severe abdominal pain with later an urticaria, allergy is considered. If the roentgenologist reports the gall bladder functioning satisfactorily, the evidence in favor of allergy is made stronger.

JOHN M. MILES, M.D.

GASTRO-INTESTINAL TRACT (THERAPY)

Gastro-intestinal Dysfunction. Barton A. Rhinehart. Southwestern Med., November, 1937, 21, 391-398.

Gastro-intestinal dysfunction, as defined by the author, applies to conditions of the alimentary canal which are not the result of organic changes. It includes dyspepsia, colitis, chronic gastritis, nervous indigestion, etc.

All the symptoms are due to increased irritability or increased functional activity of neural and muscular tissues. The symptomatology is identical with that of tetany. The common factor in this group of disorders is nutritional deficiency and this is chiefly of calcium and vitamin D.

The treatment recommended is rest, correction of nutritional deficiencies, and surgical correction of localized disease complications. Plenty of meat, milk, and sunshine and the avoidance of excess of fruits, vegetables, and physic medicines are advised.

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GENITO-URINARY TRACT (DIAGNOSIS)

Development of a Hydronephrosis by an Aberrant Vessel. R. Bauer. Röntgenpraxis, March, 1937, 9, 160-163.

The author found pyelographic evidence of an accessory or aberrant vessel at the uretero-pelvic junction in 16 out of 216 cases. Six times the finding was bilateral, ten times unilateral. In some cases a marked hydronephrosis develops gradually.

Conservative surgery seems indicated in the greater number of such cases. The hydronephrosis becomes slowly less marked after the obstruction has been removed by surgery. Nephrectomy is indicated only when there is very marked destruction of the kidney substance.

An intravenous pyelogram is at times of greater diagnostic value than a retrograde pyelogram, which causes some unphysiologic distortion of the ureter due to the introduction of a catheter.

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